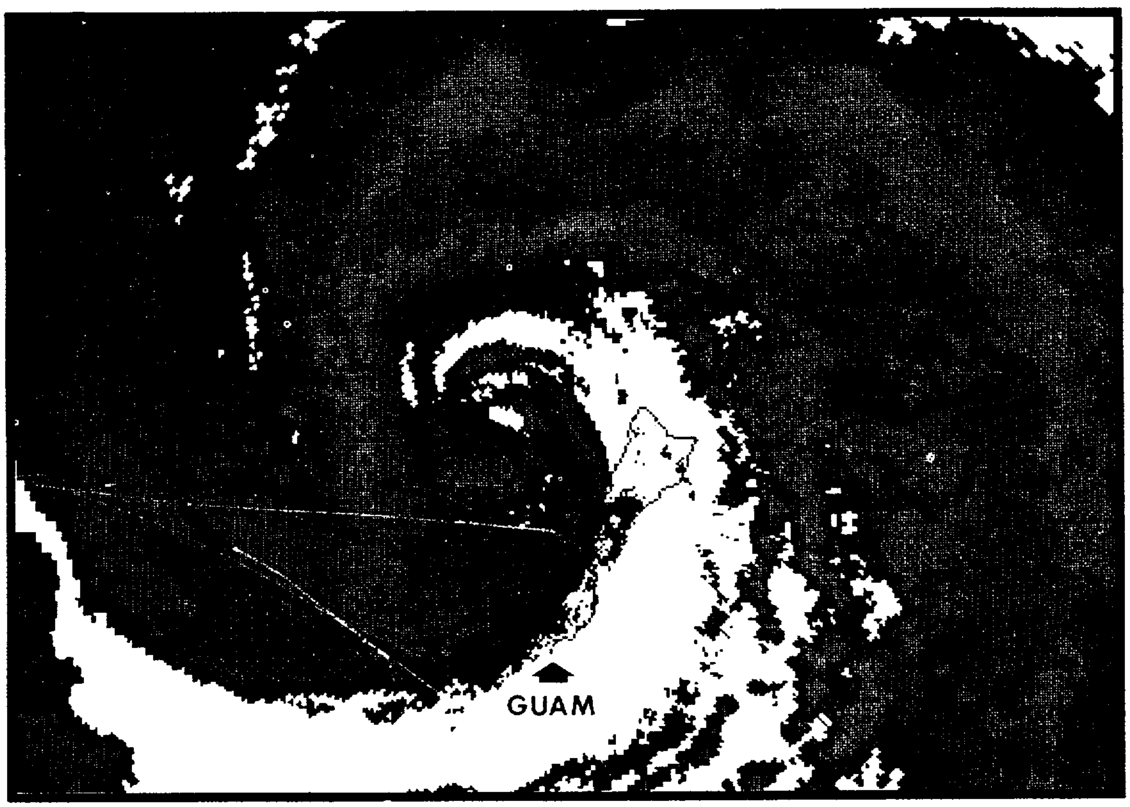
1993 ANNUAL TROPICAL CYCLONE REPORT



JOINT TYPHOON WARNING CENTER
GUAM, MARIANA ISLANDS

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY) 01-01-1995	2. REPORT TYPE Annual Report	3. DATES COVERED (FROM - TO) xx-xx-1995 to xx-xx-1995

4. TITLE AND SUBTITLE 1993 Annual Tropical Cyclone Report Unclassified	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Etro, James F. ; Morse, Peter A. ;	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME AND ADDRESS Joint Typhoon Warning Center 425 Luapele Road Pearl Harbor, HI96860-3103	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS Naval Pacific Meteorology and Oceanography Center Joint Typhoon Warning Center 425 Luapele Road Pearl Harbor, HI96860-3103	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
APUBLIC RELEASE
,

13. SUPPLEMENTARY NOTES
See Also ADM001257, 2000 Annual Tropical Cyclone Report Joint Typhoon Warning Center (CD includes 1959-1999 ATCRs). Block 1 and Block 3 should be 1993.

14. ABSTRACT
The mission of the Joint Typhoon Warning Center is multi-faceted and includes: Continuous monitoring of all tropical weather activity in the Northern and Southern Hemispheres, from 180 degrees longitude westward to the east coast of Africa, and the prompt issuance of apropriate advisories and alerts when tropical cyclone development is anticipated.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19. NAME OF RESPONSIBLE PERSON
			Public Release	253	Fenster, Lynn lfenster@dtic.mil
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER International Area Code Area Code Telephone Number 703767-9007 DSN 427-9007

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39.18

Front Cover Caption: As viewed on 301604Z September by the Andersen AFB, Guam Next Generation (Doppler Weather) Radar (NEXRAD), the bands of precipitation associated with Tropical Storm Ed (25W) tightly coil just to the west of the island..

U. S. NAVAL PACIFIC METEOROLOGY AND OCEANOGRAPHY CENTER WEST
JOINT TYPHOON WARNING CENTER
COMNAVMARIANAS
PSC 489, BOX 12
FPO AP 96536-0051

JAMES F. ETRO

CAPTAIN, UNITED STATES NAVY
COMMANDING OFFICER

PETER A. MORSE

LIEUTENANT COLONEL, UNITED STATES AIR FORCE
DIRECTOR, JOINT TYPHOON WARNING CENTER
COMMANDER, DETACHMENT 1, 633d OPERATIONS SUPPORT SQUADRON

The work on which this report is based was supported in part by funds provided by the Office of Naval Research Grant N00014-91-J1721

STAFF

JOINT TYPHOON WARNING CENTER

LCDR	ANTHONY A. MARTINEZ	USN	TDO, DEPUTY DIRECTOR
LCDR	TERESA M. GOBEL	USN	TDO, DEPUTY DIRECTOR
LCDR	ERNEST P. PETZRICK	USN	TDO
*CAPT	STEPHEN C. HALLIN	USAF	TDO, TECHNIQUE DEVELOPMENT
CAPT	ELIZABETH B. BORELLI	USAF	TDO, TECHNIQUE DEVELOPMENT
CAPT	JOHN A. RUPP	USAF	TDO
*LT	THOMAS H. CECERE	USN	TDO
LT	GREGORY SALVATO	USN	TDO
LT	PAUL E. MATTHEWS	USN	TDO
**LT	STACY R. STEWART	USNR	TDO
AG2	SCOTT E. McKEE	USN	TDA, LPO
AG2	BONNIE J. CAMPBELL	USN	TDA, STATISTICS
*AG3	MARK A. WIREMAN	USN	TDA
SRA	VINCENT L. PETRASEK	USAF	TDA
SRA	LESLEY R. ROUELL	USAF	TDA
*AGAN	PHARAOH J. BELL	USN	TDA
AGAN	GARY M. VINES	USN	TDA
A1C	SEAN R. VOLOM	USAF	TDA
*A1C	STACY L. SIMON	USAF	TDA

DET 1, 633 OSS

CAPT	CHRISTOPHER K. BROOKS	USAF	OIC, USPACOM SAT NETWORK
*CAPT	SCOTT C. JACOBS	USAF	DATA DEVELOPMENT
*MSGT	JOY L. HARDING	USAF	SAT FORECASTER, NCOIC
*MSGT	PHILLIP A. ROSEBERRY	USAF	SAT FORECASTER
*MSGT	TERESA A. deBOER	USAF	SAT FORECASTER
*MSGT	WILLIAM GATES, JR.	USAF	SAT FORECASTER
MSGT	KARL H. STEVENS	USAF	SAT FORECASTER, NCOIC
TSGT	VINCENT T. AGUON	USAF	CHIEF INFORMATION MANAGEMENT
*TSGT	JEFFREY E. OAKES	USAF	SAT FORECASTER
TSGT	THEODORE V. MUSTAIKES, JR.	USAF	SAT FORECASTER
*TSGT	JAMES G. BROCK	USAF	SAT FORECASTER
TSGT	RICHARD J. CONKLIN	USAF	DATA DEVELOPMENT
TSGT	HAROLD D. EIFERT	USAF	SAT FORECASTER
SSGT	RICHARD D. JACOBSEN	USAF	SAT FORECASTER
SSGT	JEWEL K. TAPPY	USAF	SAT FORECASTER

ATCR STAFF

CAPT	JOHN S. SHATTUCK	USAF	TDO, BEST TRACK OFFICER, EDITOR
CAPT	DAN B. MUNDELL	USAF	TDO, STATISTICS OFFICER
MR	FRANK H. WELLS	USN	TECHNICAL EDITOR
AG3	DAVID L. HAZEL	USN	TDA, GRAPHICS
AGAN	ANDRES G. GRANT	USN	TDA, GRAPHICS

UNIVERSITY OF GUAM / JTWC RESEARCH LIAISON

DR	MARK A. LANDER	TROPICAL CYCLONE RESEARCH
MR	CHARLES P. GUARD	TROPICAL CYCLONE RESEARCH

* TRANSFERRED DURING 1993
** ACTIVE DUTY TRAINING

FOREWORD

The Annual Tropical Cyclone Report is prepared by the staff of the Joint Typhoon Warning Center (JTWC), a combined Air Force/Navy organization operating under the command of the Commanding Officer, U.S. Naval Pacific Meteorology and Oceanography Center West (NAVPACMETOCCEN WEST)/Joint Typhoon Warning Center, Guam. The JTWC was founded 1 May 1959 when the U.S. Commander-in-Chief Pacific (USCINCPAC) forces directed that a single tropical cyclone warning center be established for the western North Pacific region. The operations of JTWC are guided by USCINCPAC Instruction 3140.1V.

The mission of JTWC is multifaceted and includes:

1. Continuous monitoring of all tropical weather activity in the Northern and Southern Hemispheres, from 180° east longitude westward to the east coast of Africa, and the prompt issuance of appropriate advisories and alerts when tropical cyclone development is anticipated.

2. Issuance of warnings on all significant tropical cyclones in the above area of responsibility.

3. Determination of requirements for tropical cyclone reconnaissance and assignment of appropriate priorities.

4. Post-storm analysis of significant tropical cyclones occurring within the western North Pacific and North Indian Oceans.

5. Cooperation with the Naval Research Laboratory, Monterey, California on operational evaluation of tropical cyclone models and forecast aids, and the development of new techniques to support operational forecast requirements.

Special thanks to: Captain Donald A. Mautner for his leadership, Lieutenant Colonel (Retired) Charles P. Guard for his outstanding contributions and support to the JTWC over the past four years; the men and women of the Alternate Joint Typhoon Warning Center for standing in for JTWC which was briefly incapacitated after Guam experienced a magnitude 8.2 earthquake; Fleet Numerical Meteorology and Oceanography Center (FLENUMETOCCEN) for their unfaltering operational and software support; the Naval Research Laboratory for its dedicated research and forecast improvement initiatives; the Air Force Global Weather Central for continued satellite support; the 633d Communications Squadron, Defense Meteorological Satellite Program (DMSP) Site 18 at Nimitz Hill, Guam; and the Operations and Equipment Support departments of NAVPACMETOCCEN WEST, Guam for their high quality support; all the men and women of the ships and facilities ashore throughout the JTWC area of responsibility (AOR), and especially on Guam, who took the observations that became the basis for our analyses, forecasts and post analyses; the staff at National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) for their tropical cyclone position and intensity estimates; the personnel of Tropical Cyclone Motion-1993 (TCM-93) for sharing their data and understanding of tropical cyclones; the personnel of the Pacific Fleet Audio-Visual Center, Guam for their assistance in the reproduction of satellite imagery for this report; the Navy Publications and Printing Service Branch Office, Guam; Dr. Robert F. Abbey Jr. and the Office of Naval Research for their support to the University of Guam for the JTWC Research Liaisons to JTWC; the University of Guam Research Liaison's for their important contributions to this publication; Dr. Mark Lander for his training efforts, suggestions and valuable insights; and, AG3 Dave Hazel and AGAN Andy Grant for their excellent desktop publishing and graphics.

EXECUTIVE SUMMARY

The 1993 tropical season was a challenging period for the Joint Typhoon Warning Center, Guam (JTWC). Although the North Indian Ocean stayed relatively inactive and the Southern Hemisphere followed climatology; the western North Pacific was very active with 38 tropical cyclones. Overall activity was 15 percent above normal. JTWC issued 1146 warnings distributed over 280 days. Multiple-storm scenarios in our 53 million square mile area were frequent, occurring for 91 days with two or more cyclones and 29 days with three or more. Det 1, 633 Operational Support Squadron and the USPACOM Satellite Reconnaissance Network supported us with more than 4800 fixes. The 67 storms in the JTWC area of responsibility represented nearly 80 percent of the world's tropical cyclones.

The season highlights included Ed and Flo's Fujiwhara confrontation for dominance, Yancy striking southern Japan as a thirty-year typhoon, the preponderance of late season storms bringing a record 20 systems to the Philippines, the multiple-centered 1100 nautical mile circulation of Hattie, and the Next Generation Doppler Weather Radar's (NEXRAD) introduction to tropical meteorology.

Depicted on the cover graphic is Tropical Storm Ed seen from the Guam NEXRAD. The highlight of the season for our local community was that Guam enjoyed a respite from the five typhoons of 1992, recording only a single gust of 53 knots.

The JTWC track forecast errors for the western North Pacific were 112, 213, and 325 nautical miles at the 24, 48, and 72-hour points. This amounts to four, six, and seven percent improvements on the fifteen-year averages. The climatology-persistence model, CLIPER, trailed JTWC by 15 percent with errors of 129, 245, and 368 nautical miles. Forecast intensity errors were also better than historical averages with 10.7, 17.4, and 22.9 knots compared to 12.5, 19.1, and 23.5. Track forecast errors for the North Indian Ocean and Southern Hemisphere were also good. The two "well-behaved" storms in the Northern I.O. resulted in errors of 125, 198, and 231 nautical miles representing four, ten, and 30 percent improvements. Forecast errors on the 27 Southern Hemisphere cyclones were the lowest in JTWC's 12-year history of forecasting in the region at 102 and 199 nautical miles for the 24 and 48-hour forecast points.

TABLE OF CONTENTS

1. OPERATIONAL PROCEDURES

1.1 GENERAL

The Joint Typhoon Warning Center (JTWC) provides a variety of routine products and services to the organizations within its area of responsibility (AOR), including:

1.1.1 SIGNIFICANT TROPICAL WEATHER ADVISORY — Issued daily or more frequently as needed, to describe all tropical disturbances and their potential for further development during the advisory period. A separate bulletin is issued for the western Pacific and the Indian Ocean.

1.1.2 TROPICAL CYCLONE FORMATION ALERT — Issued in a specified area when synoptic, satellite, or other germane data indicate that the development of a significant tropical cyclone is likely within 12 to 24 hours.

1.1.3 TROPICAL CYCLONE/ TROPICAL DEPRESSION WARNING — Issued periodically throughout each day to provide forecasts of position, intensity, and wind distribution for tropical cyclones in JTWC's AOR.

1.1.4 PROGNOSTIC REASONING MESSAGE — Issued with warnings for tropical storms, typhoons and super typhoons in the western North Pacific to discuss the rationale for the content of the specific JTWC warning.

1.1.5 PRODUCT CHANGES — The contents and availability of the above JTWC products are set forth in USCINCPACINST 3140.1V. Changes to USCINCPACINST 3140.1V, and JTWC products and services are proposed and discussed at the Annual Tropical Cyclone Conference.

1.2 DATA SOURCES

1.2.1 COMPUTER PRODUCTS — Numerical and statistical guidance are available from the USN Fleet Numerical Meteorology and Oceanography Center (FLENUMETOCCEN) at Monterey, California. These products along with selected ones from the National Meteorological Center (NMC) Suitland Maryland are received through the Naval Environmental Data Network (NEDN), the Naval Environmental Satellite Network (NESN), and by microcomputer dial-up connections using military and commercial telephone lines. Numerical guidance is also received from international sources as well.

1.2.2 CONVENTIONAL DATA — These data sets are comprised of land and shipboard surface observations, and enroute meteorological observations from commercial and military aircraft (AIREPS) recorded within six hours of synoptic times, and cloud-motion winds derived from satellite data. The conventional data is hand- and computer-plotted, and hand-analyzed in the tropics for the surface/gradient and 200-mb levels. These analyses are prepared twice daily from 0000Z and 1200Z synoptic data. Also, FLENUMETOCCEN supplies JTWC with computer generated analyses and prognoses, from 0000Z and 1200Z synoptic data, at the surface, 850-mb, 700-mb, 500-mb, 400-mb, and 200-mb levels, deep-layer-mean winds, wind shear, and geopotential height-change charts.

1.2.3 SATELLITE RECONNAISSANCE — Meteorological satellite imagery recorded at USAF/USN ground sites and USN ships supply day and night coverage in JTWC's AOR. Interpretation of these satellite data provides tropical cyclone positions and estimates of cur-

rent and forecast intensities (Dvorak, 1984). The USAF tactical satellite sites and Air Force Global Weather Central (AFGWC) currently receive and analyze special sensor microwave/imager (SSM/I) data to provide locations of tropical cyclones of which the center is obscured by cirrus clouds, and estimates of 35-kt (18 m/sec) wind radii near tropical cyclones. Use of satellite reconnaissance is discussed further in section 2.3, Satellite Reconnaissance Summary.

1.2.4 RADAR RECONNAISSANCE — Land-based radar observations are used to position tropical cyclones. Once a well-defined tropical cyclone moves within the range of land-based radar sites, radar reports are invaluable for determination of position, movement, and, in the case of Doppler radar, storm structure and wind information. JTWC's use of radar reports during 1993 is discussed in section 2.4, Radar Reconnaissance Summary.

1.2.5 AIRCRAFT RECONNAISSANCE — Until the summer of 1987, dedicated aircraft reconnaissance was used routinely to locate and determine the wind structure of tropical cyclones. Now, aircraft fixes are only available via radar reports from transiting jet aircraft or from weather reconnaissance aircraft involved in tropical cyclone research missions. Six fixes were received from aircraft supporting the Tropical Cyclone Motion-1993 (TCM-93) experiment.

1.2.6 DRIFTING METEOROLOGICAL BUOYS — In 1989, the Commander, Naval Meteorology and Oceanography Command (COMNAVMETOCCOM) put its Integrated Drifting Buoy Plan (1989-1994) into action to meet USCINCPACFLT requirements that included tropical cyclone warning support. In 1993, 19 drifting buoys, which included 16 mini-meteorological (MINI-MET) and three larger TOGA buoys, were deployed during the WESTPAC tropical cyclone season by a Naval Oceanographic Office-contracted C-130 aircraft.

These buoys transmit data to National Oceanic and Atmospheric Administration's (NOAA) Television and Infrared Operational Satellite - Next Generation (TIROS-N) polar orbiting satellites, which in turn both store and immediately retransmit the data. If the satellite retransmission can be received by Guam, JTWC acquires the drifting buoy observations directly via a Local User's Terminal (LUT). Additionally, the data stored aboard the satellites are recovered via Service ARGOS, processed, and then distributed to operational centers worldwide over the Global Telecommunications System (GTS) and Automated Weather Network (AWN) via the National Weather Service (NWS) Telecommunications Gateway in Silver Springs, Maryland.

1.2.7 AUTOMATED METEOROLOGICAL OBSERVING STATIONS (AMOS) — Through a cooperative effort between the COMNAVMETOCCOM, the Department of the Interior, and NOAA/NWS to increase data available for tropical analysis and forecasting, a network of 20 AMOS stations is being installed in the Micronesian islands (see Tables 1-1 and 1-2). Previous to this effort, two sites were installed in the Northern Mariana Islands at Saipan and Rota through a joint venture between the Navy and NOAA/NWS. The site at Saipan has since been moved to Tinian. Since September of 1991, the capability to transmit data via Service ARGOS and NOAA polar orbiting satellites has been available as a backup to regular data transmission to the Geostationary Operational Environmental Satellite (GOES) West, and more recently for sites to the west of Guam, to the Japanese Geostationary Meteorological Satellite (GMS). Upgrades to existing sites are also being accomplished as the opportunity arises to enable access to the ARGOS-system.

Table 1-1 AUTOMATED METEOROLOGICAL OBSERVING STATIONS SUMMARY

Site	Location	Call sign	ID#	System	Installed
Saipan*	15.2°N, 145.7°E	15D151D2	-----	ARC	1986
Rota	14.2°N, 145.2°E	15D16448	91221	ARC	1987
Faraulep**	8.1°N, 144.6°E	FARP2	52005	C-MAN/ARGOS	1988
Enewetak	11.4°N, 162.3°E	ENIP2	91251	C-MAN/ARGOS	1989
Ujae**	8.9°N, 165.8°E	UJAP2	91365	C-MAN	1989
Pagan	18.1°N, 145.8°E	PAGP2	91222	C-MAN/ARGOS	1990
Kosrae	5.3°N, 163.0°E	KOSP2	91355	C-MAN/ARGOS	1990
Mili	6.1°N, 171.8°E	MILP2	91377	C-MAN	1990
Oroluk	7.6°N, 155.1°E	ORKP2	91343	C-MAN	1991
Pingelap	6.3°N, 160.7°E	PIGP2	91352	C-MAN/ARGOS	1991
Ulul	8.7°N, 149.7°E	-----	91328	C-MAN/ARGOS	1992
Tinian*	15.0°N, 145.6°E	15D151D2	91231	ARC	1992

* Saipan site relocated to Tinian and commissioned on 1 June 1992.

** The prototype site on Faraulep was destroyed on 28 November 1991 by Super Typhoon Owen.

*** Ujae site was destroyed on 18 November 1992 by Super Typhoon Gay.

ARC = Automated Remote Collection system (via GOES West)
C-MAN = Coastal-Marine Automated Network (via GOES West or GMS)
ARGOS = Service ARGOS data collection (via NOAA's TIROS-N)

Table 1-2 PROPOSED AUTOMATED METEOROLOGICAL OBSERVING STATIONS

Site	Location	Installation	Delayed
Pulusuk	6.5°N, 149.5°E	1993	Yes*
Ulithi	10.1°N, 139.8°E	1993	Yes**
Ngulu	8.3°N, 137.5°E	1993	Yes**
Faraulep	8.1°N, 144.6°E	1994	Yes**
Eauripik	6.7°N, 143.0°E	1994	Yes**
Maloelap	8.7°N, 171.2°E	1994	No
Utirik	11.2°N, 169.8°E	1994	No
Satawal	7.3°N, 147.0°E	1995	No
Ujelang	9.8°N, 160.9°E	1995	No
Ebon	4.6°N, 168.7°E	1995	No
Maug	20.0°N, 145.2°E	1996	No

* Runway construction

** Testing of GMS transmission packages

JTWC receives data from all AMOS sites via the AWN under the KWBC bulletin headers SMPW01, SIPW01 and SNPW01 (SXMY10 for Tinian and Rota).

1.3 COMMUNICATIONS

Primary communications support is provided by the Naval Telecommunications Center (NTCC), Nimitz Hill, a component of the Naval Computers and Telecommunications Area Master Station, Western Pacific (NCTAMS WESTPAC). Communications systems available to JTWC follow.

1.3.1 AUTOMATED DIGITAL NETWORK (AUTODIN) — AUTODIN is used for dissemination of warnings, alerts and other related bulletins to Department of Defense (DOD) and other US Government installations. These messages are relayed for further transmission over Navy Fleet Broadcasts, and Coast Guard continuous wave Morse code and voice broadcasts. AUTODIN messages can be relayed to commercial telecommunications for delivery to non-DOD users. Inbound message traffic for JTWC is received via AUTODIN addressed to NAVPACMETOCCEN WEST GU//JTWC// or DET 1 633 OSS NIMITZ HILL GU//CC//.

1.3.2 AUTOMATED WEATHER NETWORK (AWN) — The AWN provides weather data over the Pacific Meteorological Data System (PACMEDS). The PACMEDS, operational at JTWC since April 1988, allows Pacific-Theater agencies to receive weather information at a 1200 baud rate. JTWC uses a software package called AWNCOM/WINDS on a microcomputer to send and receive data via the PACMEDS. This system provides effective storage and manipulation of the large volume of meteorological reports available from throughout JTWC's vast AOR. Through the AWN, JTWC has access to data available on the Global Telecommunications System (GTS). JTWC's AWN station identifier is PGTW.

1.3.3 DEFENSE SWITCHED NETWORK (DSN) — DSN, formerly AUTOVON, is a worldwide, general purpose, switched telecommunications network for the DOD. The network provides a rapid and vital voice link for JTWC to communicate tropical cyclone information to DOD installations. The DSN telephone numbers for JTWC are 344-4224 or 344-5240.

1.3.4 NAVAL ENVIRONMENTAL DATA NETWORK (NEDN) — The NEDN is the primary link to FLENUMETOCCEN to obtain computer-generated analyses and prognoses. It is also a backup communications line for requesting and receiving the objective tropical cyclone forecast aids from FLENUMETOCCEN's mainframe computers. The NEDN allows JTWC to communicate directly to the other COMNAVMETOCCOM Centers around the world.

1.3.5 PUBLIC DATA NETWORK (PDN) — A commercial packet switching network that provides low-speed interactive transmission to users of FLENUMETOCCEN products. The PDN is now the primary method for JTWC to request and receive FLENUMETOCCEN-produced objective tropical cyclone forecast aids. The PDN allows direct access of FLENUMETOCCEN products via the Automated Tropical Cyclone Forecast (ATCF) system. The PDN also serves as an alternate method of obtaining FLENUMETOCCEN analyses and forecast fields. Time-sharing Network (TYMNET) is the contractor providing PDN services between FLENUMETOCCEN and JTWC.

1.3.6 DEFENSE DATA NETWORK (DDN) — The DDN is a DOD computer communications network utilized to exchange data files. Because the DDN has links, or gateways, to

military information networks, it is frequently used to exchange data with the research community. JTWC's internet address is 26.19.0.250 and its E-mail account is jtops@nocc.navy.mil. The Det 1, 633d OSS address is admin@nocc.navy.mil.

1.3.7 TELEPHONE FACSIMILE — TELEFAX provides the capability to rapidly scan and transmit, or receive, documents over commercial telephone lines or DSN. TELEFAX is used to disseminate tropical cyclone advisories and warnings to key agencies on Guam and, in special situations, to DOD, other U.S. Government agencies, and the other Micronesian Islands. Inbound documents for JTWC are received at (671) 344-6143, (671) 344-6106 or (671) 344-4032.

1.3.8 NAVAL ENVIRONMENTAL SATELLITE NETWORK (NESN) — The NESN's primary function is to pass satellite data from the satellite global data base at FLENUMETOCCEN to regional centers. Similarly, it can pass satellite data from NAVPACMETOCCEN WEST/JTWC to FLENUMETOCCEN or other regional centers. It also provides a limited backup for the NEDN.

1.3.9 AIRFIELD FIXED TELECOMMUNICATIONS NETWORK (AFTN) — AFTN was installed at JTWC in January 1990. Though it is primarily for the exchange of aviation information, weather information and warnings are also distributed via this network. It also provides point-to-point communication with other warning agencies not connected to the AWN or GTS. JTWC's AFTN identifier is PGUMYMYT.

1.3.10 LOCAL USER TERMINAL (LUT) — JTWC uses a LUT, provided by the Naval Oceanographic Office, as the primary means of receiving real-time data from drifting meteorological buoys and ARGOS-equipped AMOS via the polar orbiting TIROS-N satellites.

1.3.11 COMPUTER FACSIMILE — The NAVPACMETOCCEN WEST/JTWC Rapid Response Team (RRT) uses a microcomputer to automatically transmit facsimile messages to agencies on Guam and the Northern Mariana Islands when a tropical cyclone threatens. The RRT can be reached at (671) 344-7116 or (671) 344-7119.

1.3.12 TELEX — NAVPACMETOCCEN WEST/JTWC's address for inbound TELEX messages is 197873NOCC GU.

1.4 DATA DISPLAYS

1.4.1 NAVAL ENVIRONMENTAL DISPLAY STATION (NEDS) — The NEDS receives, processes, stores, displays and prints copies of FLENUMETOCCEN environmental products. It drives the fleet facsimile broadcast and can also be used to generate the requests for objective tropical cyclone forecast techniques.

1.4.2 AUTOMATED TROPICAL CYCLONE FORECAST SYSTEM (ATCF) — The ATCF is an advanced software program that assists the Typhoon Duty Officer (TDO) in the preparation, formatting, and dissemination of JTWC's products. It cuts message preparation time and reduces the number of corrections. The ATCF automatically displays: the working and objective best tracks; forecasts of track, intensity, and wind distribution; and, information from computer generated forecast aids and products from other agencies. It also and computes the myriad of statistics calculated by JTWC. Links have been established through a Local Area Network (LAN) to the NAVPACMETOCCEN WEST Operations watch team to facilitate the generation of tropical cyclone warning graphics for the fleet facsimile broadcasts, for NAVPACMETOCCEN WEST's local metwatch program,

and for warning products for Micronesia. A module permits satellite reconnaissance fixes to be input from Det 1, 633d OSS into the LAN. Several other modules are still under development including direct links to NTCC, the LUT, and the AWN.

1.4.3 NAVAL SATELLITE DISPLAY SYSTEM (NSDS) — The NSDS functions as a display of FLENUMETOCCEN-stored Defense Meteorological Satellite Program (DMSP) imagery and low resolution geostationary imagery. It is the primary means for JTWC to directly observe areas of cloudiness in the western Indian Ocean.

1.4.4 NAVAL SATELLITE DISPLAY SYSTEM-GEOSTATIONARY (NSDS-G) — The NSDS-G is NAVPACMETOCCEN WEST's primary geostationary imagery processing and display system. It can be used to process high resolution geostationary imagery for analysis of tropical cyclone positions and intensity estimates for the western Pacific Ocean should the the Meteorological Imagery, Data Display, and Analysis System (MIDDAS) fail.

1.5 ANALYSES

The JTWC TDO routinely performs manual streamline analyses of composite surface/gradient-level (3000 ft (914 m)) and upper-tropospheric (centered on the 200-mb level) data for 0000Z and 1200Z daily. Manual sea-level pressure analyses concentrating on the mid-latitudes are available from the NAVPACMETOCCEN WEST Operations watch team. Computer analyses of the surface, 925-, 850-, 700-, 500-, 400-, and 200-mb levels, deep-layer-mean winds, frontal boundaries depiction, 1000-200 mb/400-200 mb/and 700-400 mb wind shear, 500 mb and 700 mb 24-hour height change, and a variety of other meteorological displays come from the 0000Z and 1200Z FLENUMETOCCEN data bases. Additional sectional charts at intermediate synoptic times and auxiliary charts, such as station-time plot diagrams, time-height cross section charts and pressure-change charts, are analyzed during periods of significant tropical cyclone activity.

1.6 FORECAST PROCEDURES

1.6.1 INITIAL POSITIONING — The warning position is the best estimate of the center of the surface circulation at synoptic time. It is estimated from an analysis of all fix information received from one hour before to one and one-half hours after that synoptic time. The analysis is aided by a computer-generated objective best track scheme that weights fix information based on its statistical accuracy. The TDO includes synoptic observations and other information to adjust the position, testing consistency with the past direction, speed of movement and the influence of the different scales of motions. If the fix data are not available due to reconnaissance platform malfunction or communication problems, or are considered unrepresentative, synoptic data and/or extrapolation from previous fixes are used.

1.6.2 TRACK FORECASTING — In preparing the JTWC official forecast, the TDO evaluates a wide variety of information, and employs a number of objective and subjective techniques. Because tropical cyclone track forecasting has and continues to require a significant amount of subjective input from the TDO, detailed aspects of the forecast-development process will vary somewhat from TDO to TDO, particularly with respect to the weight given to any of the available guidance. JTWC uses a standardized, three-phase tropical cyclone motion forecasting process to improve not only track forecast accuracy, but also intensity forecast accuracy and forecast-to-forecast consistency.

1.6.2.1 Field Analysis Phase — Navy Operational Global Atmospheric Prediction System (NOGAPS) analyses and prognoses at various levels are evaluated for position, development, and movement of not only the tropical cyclone, but also relevant synoptic features such as: 1) subtropical ridge circulations, 2) mid-latitude short/long-wave troughs and associated weaknesses in the subtropical ridge, 3) monsoon surges, 4) influences of cyclonic cells in the Tropical Upper-Tropospheric Trough (TUTT), 5) other tropical cyclones, and 6) the distribution of sea surface temperature. This process permits the TDO to develop an initial impression of the environmental steering influences to which the tropical cyclone is and will be subjected to as depicted by NOGAPS. The NOGAPS analyses are then compared to the hand-plotted and analyzed charts prepared by the TDO and to the latest satellite imagery in order to determine how well the NOGAPS-initialization process has conformed to the available synoptic data, and how well the resultant analysis fields agree with the synoptic situation inferred from the imagery. Finally, the TDO compares both the computer and hand-analyzed charts to monthly climatology in order to make a preliminary determination of to what degree the tropical cyclone is, and will continue to be, subjected to a climatological or nonclimatological synoptic environment. Noting latitudinal and longitudinal displacements of subtropical ridge and long-wave midlatitude features is of particular importance, and will partially determine the relative weights given to climatologically- or dynamically-based objective forecast guidance.

1.6.2.2 Objective Techniques Analysis Phase — After displaying the latest set of forecasts given by JTWC's suite of objective techniques, the TDO then evaluates the pattern produced by the set of forecasts according to the following principles. First, the degree to which the current situation is considered to be, and will continue to be, climatological is further refined by comparing the forecasts of the climatology-based objective techniques, dynamically-based techniques, and past motion of the present storm. This assessment partially determines the relative weighting given the different classes of objective techniques. Second, the spread of the pattern determined by the set of objective forecasts is used to provide a measure of the predictability of subsequent motion, and the advisability of including a moderate probability alternate forecast scenario in the prognostic reasoning message or warning (outside the western North Pacific). The directional spread of the objective techniques pattern is typically small well-before or well-after recurvature (providing high forecast confidence), and is typically large near the decision-point of recurvature or non-recurvature, or during a quasi-stationary or erratic movement phase. A large spread increases the likelihood of alternate forecast scenarios.

1.6.2.3 Construct Forecast Phase — The TDO then constructs the JTWC official forecast giving due consideration to the: 1) extent to which the synoptic situation is, and is expected to remain, climatological; 2) past statistical performance of the various objective techniques on the current storm; and, 3) known properties of individual objective techniques given the present synoptic situation or geographic location. The following guidance for weighting the objective techniques is applied:

a) Weight persistence strongly in the first 12 to 24 hours of the forecast period.

b) Give significant weight to the last JTWC forecast at all forecast times, unless there is significant evidence to warrant a departure. (Also consider the latest forecasts from regional warning centers, if applicable.)

c) Give more weight to the techniques that have been performing well on the current tropical cyclone and/or are expected to perform well in the current and anticipated synoptic situations.

d) Stay within the "envelope" determined by

the spread of objective techniques forecasts unless there is a strong specific reason for not doing so (e.g., all objective forecasts start out at a significant angle relative to past motion of the current tropical cyclone).

1.6.3 INTENSITY FORECASTING — The empirically derived Dvorak (1984) technique is used as a first guess for the intensity forecast. The TDO then adjusts the forecast after evaluating climatology and the synoptic situation. An interactive conditional climatology scheme allows the TDO to define a situation similar to the system being forecast in terms of location, time of year, current intensity, and intensity trend. Synoptic influences such as the location of major troughs and ridges, and the position and intensity of the TUTT all play a large part in intensifying or weakening a tropical cyclone. JTWC incorporates a checklist into the intensity forecast procedure. Such criteria as upper-level outflow patterns, neutral points, sea-surface temperatures, enhanced monsoonal or cross-equatorial flow, and vertical wind shear are evaluated for their tendency to enhance or inhibit normal development, and are incorporated into the intensity forecast process through locally developed thumb rules. In addition to climatology and synoptic influences, the first guess is modified for interactions with land, with other tropical cyclones, and with extratropical features. Climatological and statistical methods are also used to assess the potential for rapid intensification (Mundell, 1990).

1.6.4 WIND-RADII FORECASTING — Since the loss of dedicated aircraft reconnaissance in 1987, JTWC has turned to other data sources for determining the radii of winds around tropical cyclones. The determination of wind radii forecasts is a three-step process:

(a) first, low-level satellite drift winds, microwave imager 35-kt wind speed analysis (See Chapter 2), and synoptic data are used to derive the current wind distribution.

(b) next the first guess of the radii is determined from statistically-derived empirical wind radii models. JTWC currently used three models: the Tsui model, the Huntley model, and the Martin-Holland model. The latter model uses satellite-derived parameters to determine the size and shape of the wind profile associated with a particular tropical cyclone. The Martin-Holland model also incorporates latitude and speed of motion to produce an asymmetrical wind distribution. These models provide wind distribution analyses and forecasts that are primarily influenced by the intensity forecasts. The analyses are then adjusted based on the actual analysis from step (a), and the forecasts are adjusted appropriately.

(c) Finally, synoptic considerations, such as the interaction of the cyclone with mid-latitude high pressure cells, are used to fine-tune the forecast wind radii.

1.6.5 EXTRATROPICAL TRANSITION — When a tropical cyclone moves into the mid-latitudes, if often enters an environment that is detrimental to the maintenance of the tropical cyclone's structure and energy-producing mechanisms. The effects of cooler sea surface temperatures, cooler and dryer environmental air, and strong vertical wind shear all act to convert the tropical cyclone into an extratropical cyclone. JTWC indicates that this conversion process is occurring by stating that the tropical cyclone is "becoming extratropical." JTWC will indicate that the conversion is expected to be complete by stating that the system has become "extratropical." When a tropical cyclone is forecast to become extratropical, JTWC coordinates the transfer of responsibility with the appropriate regional NAVPACMETOCCEN, which assumes warning responsibility for the extratropical system.

1.6.6 TRANSFER OF WARNING RESPONSIBILITY — JTWC coordinates the transfer of warning responsibility for tropical cyclones

entering or exiting its AOR. For tropical cyclones crossing 180° east longitude in the North Pacific Ocean, JTWC coordinates with the Central Pacific Hurricane Center (CPHC), Honolulu via the Naval Western Oceanography Center (NAVPACMETOCCEN), Pearl Harbor, Hawaii. For tropical cyclones crossing 180° east longitude in the South Pacific Ocean, JTWC coordinates with the NAVPACMETOC-CEN, which has responsibility for the eastern South Pacific. Whenever a tropical cyclone threatens Guam, files are electronically transferred from JTWC to the Alternate Joint Typhoon Warning Center (AJTWC) collocated with NAVPACMETOCCEN. In the event that JTWC should become incapacitated, the AJTWC assumes JTWC's functions. Assistance in determining satellite reconnaissance requirements, and in obtaining the resultant data, is provided by the weather unit supporting the 15th Air Base Wing, Hickam AFB, Hawaii.

1.7 WARNINGS

JTWC issues two types of warnings: Tropical Cyclone Warnings and Tropical Depression Warnings.

1.7.1 TROPICAL CYCLONE WARNINGS — These are issued when a closed circulation is evident and maximum sustained 1-minute winds are forecast to reach 34 kt (18 m/sec) within 48 hours, or when the tropical cyclone is in such a position that life or property may be endangered within 72 hours.

Each Tropical Cyclone Warning is numbered sequentially and includes the following information: the current position of the surface center; an estimate of the position accuracy and the supporting reconnaissance (fix) platform(s); the direction and speed of movement during the past six hours (past 12 hours in the Southern Hemisphere); and the intensity and radial extent of over 35-, 50-, and 100-kt (18-, 26-, and 51 m/sec) surface winds, when applicable. At forecast intervals of 12, 24, 36, 48, and 72 hours (12, 24, and 48 hours in the Southern Hemisphere), information on the tropical cyclone's anticipated position, intensity and wind radii is provided. Vectors indicating the mean direction and mean speed between forecast positions are included in all warnings. In addition, a 3-hour extrapolated position is provided in the remarks section.

Warnings in the western North Pacific and North Indian Oceans are issued every six hours (unless an amendment is required), valid at standard times: 0000Z, 0600Z, 1200Z and 1800Z (every 12 hours: 0000Z, 1200Z or 0600Z, 1800Z in the Southern Hemisphere). All warnings are released to the communications network no earlier than synoptic time and no later than synoptic time plus two and one-half hours, so that recipients are assured of having all warnings in hand by synoptic time plus three hours (0300Z, 0900Z, 1500Z and 2100Z). By area, the warning bulletin headers are: WTIO31-35 PGTW for northern latitudes from 35° to 100° east longitude, WTPN31-36 PGTW for northern latitudes from 100° to 180° east longitude, WTXS31-36 PGTW for southern latitudes from 35° to 135° east longitude, and WTPS31-35 PGTW for southern latitudes from 135° to 180° east longitude.

1.7.2 TROPICAL DEPRESSION WARNINGS — These are issued only for western North Pacific tropical depressions that are not expected to reach the criteria for Tropical Cyclone Warnings, as mentioned above. The depression warning contains the same information as a Tropical Cyclone Warning except that the Tropical Depression Warning is issued every 12 hours (unless an amendment is required) at standard synoptic times and extends in 12-hour increments only through 36 hours.

Both Tropical Cyclone and Tropical Depression Warning forecast positions are later verified against the corresponding best track positions (obtained during detailed post-storm

analyses) to determine the most probable path and intensity of the cyclone. A summary of the verification results for 1993 is presented in Chapter 5, Summary of Forecast Verification.

1.8 PROGNOSTIC REASONING MESSAGES

These plain language messages provide meteorologists with the rationale for the JTWC forecasts for tropical cyclones in the western North Pacific Ocean. They also discuss alternate forecast scenarios, if changing conditions indicate such potential. Prognostic reasoning messages (WDPN31-36 PGTW) are prepared to complement tropical cyclone (but not tropical depression) warnings. In addition to these messages, prognostic reasoning information may be provided in the remark section of a tropical cyclone warning.

1.9 TROPICAL CYCLONE FORMATION ALERTS

Tropical Cyclone Formation Alerts are issued whenever interpretation of satellite imagery and other meteorological data indicates that the formation of a significant tropical cyclone is likely. These alerts will specify a valid period, usually not exceeding 24 hours, and must either be canceled, reissued, or superseded by a warning prior to expiration. By area, the Alert bulletin headers are: WTIO21-25 PGTW for northern latitudes from 35° to 100°E longitude, WTPN21-26 PGTW for northern latitudes from 100° to 180°E longitude, WTXS21-26 PGTW for southern latitudes from 35° to 135°E longitude, and WTPS21-25 PGTW for southern latitudes from 135° to 180°E longitude.

1.10 SIGNIFICANT TROPICAL WEATHER ADVISORIES

This product contains a description of all tropical disturbances in JTWC's AOR and their potential for further (tropical cyclone) development. In addition, all tropical cyclones in warning status are briefly discussed and referenced.

Two separate messages are issued daily, and each is valid for a 24-hour period. The Significant Tropical Weather Advisory for the Western Pacific Ocean is issued by 0600Z. The Significant Tropical Weather Advisory for the Indian Ocean is issued by 1800Z. These are reissued whenever the situation warrants. For each suspect area, the words "poor", "fair", or "good" are used to describe the potential for development. "Poor" will be used to describe a tropical disturbance in which the meteorological conditions are currently unfavorable for development. "Fair" will be used to describe a tropical disturbance in which the meteorological conditions are favorable for development, but significant development has not commenced or is not expected to occur in the next 24 hours. "Good" will be used to describe the potential for development of a disturbance covered by an Alert. By area, the advisory bulletin headers are: ABPW10 PGTW for northern latitudes from 100° to 180°E longitude and southern latitudes from 135° to 180°E longitude and ABIO10 PGTW for northern latitudes from 35° to 100°E longitude and southern latitudes from 35° to 135°E longitude.

2. RECONNAISSANCE AND FIXES

2.1 GENERAL

JTWC depends primarily on two reconnaissance platforms, satellite and radar, to provide necessary, accurate and timely meteorological information in support of advisories, alerts and warnings. When available, synoptic and aircraft reconnaissance data are also used to supplement the above. As in past years, the optimal use of all available reconnaissance resources to support JTWC's products remains a primary concern. Weighing the specific capabilities and limitations of each reconnaissance platform, and the tropical cyclone's threat to life and property, both afloat and ashore, continue to be important factors in careful product preparation.

2.2 RECONNAISSANCE AVAILABILITY

2.2.1 SATELLITE — Interpretation of satellite imagery by analysts at Air Force/Navy ground sites and on Navy ships yields tropical cyclone positions, estimates of the current intensity, and forecast intensity. Additional positioning and surface wind estimation information is available for analysis where the DMSP SSM/I data can be received and displayed.

2.2.2 RADAR — Interpretation of land-based radar, which remotely senses and maps precipitation within tropical cyclones, provides positions in the proximity (usually within 175 nm (325 km) of radar sites in the Kwajalein, Guam, Japan, South Korea, China, Taiwan, Philippine Islands, Hong Kong, Thailand, India and Australia. Where Doppler radars are located, such as the new NEXRAD installation on Guam, measurements of radial velocity are also available, and observations of the tropical cyclone's horizontal velocity field and wind structure integrated in the vertical are possible within the radar volume.

2.2.3 AIRCRAFT — Six tropical cyclone fixes were received from the weather reconnaissance aircraft associated with the TCM-93 mini-field experiment conducted near Guam during July and August. In the Southern Hemisphere, one aircraft fix on Tropical Cyclone 16P (Oliver) was logged in February 1993.

2.2.4 SYNOPTIC — JTWC also determines tropical cyclone positions based on the analysis of surface/gradient-level synoptic data. These positions are an important supplement to fixes provided by analysts using data from remote sensing platforms, and become most valuable in situations where neither satellite, radar nor aircraft fixes are available or representative.

2.3 SATELLITE RECONNAISSANCE SUMMARY

The Air Force provides satellite reconnaissance support to JTWC through the DMSP Tropical Cyclone Reporting Network (DMSP Network), which consists of several tactical sites and a centralized facility. The personnel of Det 1, 633d OSS (hereafter referred to as Det 1), collocated with JTWC at Nimitz Hill, Guam, coordinate required tropical cyclone reconnaissance support with the following units:

Unit	Call sign
15 ABW/WE, Hickam AFB, Hawaii	PHIK
18 OSS/WE, Kadena AB, Japan	RODN
603 ACCS/DOW, Osan AB, Republic of Korea	RKWU
Air Force Global Weather Central, Offutt AFB, Nebraska	KGWC

The DMSP Network sites provide a combined coverage from polar orbiting satellites that includes most of the western North Pacific, from near the international date line westward into the South China Sea. The Naval Pacific Meteorology and Oceanography Detachment at

Diego Garcia furnishes fixes through interpretation of low resolution NOAA polar orbiting satellite imagery that covers the central Indian Ocean, and Navy ships equipped for direct satellite readout contribute supplementary support. Also, civilian contractors with the U.S. Army at Kwajalein Atoll supplement Det 1's satellite coverage with fixes on tropical cyclones in the Marshall Islands and east of the date line.

Additionally, mosaics developed from DMSP satellite imagery are available from the FLENUMETOCCEN via the NEDN and NESN lines. These mosaics are used to metwatch the areas not included in the coverage of DMSP Network tactical sites. They provide JTWC forecasters with the time-delayed capability to "see" what AFGWC's satellite image analysts have been fixing.

Det 1 also uses high resolution geostationary imagery to support the reconnaissance mission. Animation of images is invaluable for determining the location and motion of cloud system centers, particularly in the formative stages. Animation is also valuable in assessing changes in the environment that affect tropical cyclone behavior. Det 1 is able to process high resolution digital geostationary data through its MIDDAS, and the Navy's GSRS. The MIDDAS consists of a network of three microcomputers, advanced graphics software, and large screen work stations that process and display geostationary imagery, NOAA High Resolution Picture Transmission (HRPT) and TIROS Operational Vertical Sounder (TOVS) data, and DMSP imagery. On 1 April 1992 the MIDDAS was formally accepted as a part of Det 1 operations. Further software upgrades of MIDDAS have extended the GMS grid 10 degrees closer to the limb of the earth's disk, and have allowed the normal projection of the GMS image to be warped into a mercator projection. These two upgrades provided a more user-friendly presentation of tropical weather systems over the Bay of Bengal and the Indian Ocean to the south. The most recent software upgrade added the capability to process and analyze DMSP SSM/I data on the MIDDAS.

In support of JTWC, AFGWC analyzes stored imagery from both the DMSP and NOAA spacecraft. These imagery are recorded and stored onboard the spacecraft for later relay to a command readout site which in turn passes the data via a communication satellite to AFGWC. This enables AFGWC to obtain the global coverage needed to monitor all tropical cyclones worldwide several times a day.

The hub of the DMSP Network is Det 1, which is responsible for coordinating satellite reconnaissance requirements with JTWC and tasking the individual network sites for the necessary tropical cyclone fixes, current intensity estimates, and SSM/I-derived surface winds. When a particular satellite pass is selected to support JTWC's next tropical cyclone warning, two sites are tasked to fix the tropical cyclone from the same pass. This "dual-site" concept provides the necessary redundancy that virtually guarantees JTWC a satellite fix to support each warning. It also supplies independent assessments of the same data to provide TDOs a measure of confidence in the location and intensity information.

The DMSP Network provides JTWC with several products and services. The main service is to monitor the AOR for indications of tropical cyclone development. If development is suspected, JTWC is notified. Once JTWC issues either a TCFA or a warning, the DMSP Network provides tropical cyclone positions and current intensity estimates, with a forecast intensity estimate implied from the code (Dvorak 1975, 1984) shown in Figure 2-1. Each satellite-derived tropical cyclone position is assigned a Position Code Number (PCN), which is a measure of positioning confidence.
The PCN is determined by a combination of 1) the availability of visible landmarks in the image that can be used as references for precise gridding, and 2) the degree of organization of

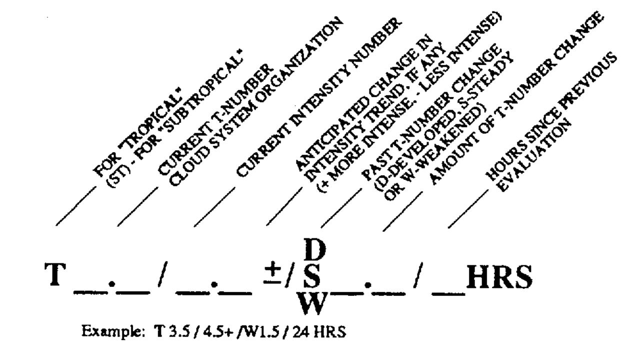


Figure 2-1 Dvorak code for communicating estimates of current and forecast intensity derived from satellite data. In the example, the current "T-number" is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the evaluation conducted 24-hours earlier. The plus (+) symbol indicates an expected reversal of the weakening trend or very little further weakening of the tropical cyclone during the next 24-hour period.

the tropical cyclone's cloud system (Table 2-1). Once the tropical cyclone's intensity reaches 50 kt (26 m/sec), the DMSP Network analyzes the distribution of SSM/I-derived 35-kt (18-m/sec) winds in the rain-free areas near the tropical cyclone.

Det 1 provides at least one estimate of the tropical cyclone's current intensity every 6 hours once JTWC is in alert or warning status. Current intensity estimates are made using the

Table 2-1 POSITION CODE NUMBER (PCN)

PCN	METHOD FOR CENTER DETERMINATION/GRIDDING
1	EYE/GEOGRAPHY
2	EYE/EPHEMERIS
3	WELL DEFINED CIRCULATION CENTER/GEOGRAPHY
4	WELL DEFINED CIRCULATION CENTER/EPHEMERIS
5	POORLY DEFINED CIRCULATION CENTER/GEOGRAPHY
6	POORLY DEFINED CIRCULATION CENTER/EPHEMERIS

Dvorak technique for both visible and enhanced infrared imagery. For the intensity analysis of mature tropical cyclones, the enhanced infrared technique is preferred due to its objectivity; however, daily use of the visible technique adds a measure of consistency and helps resolve ambiguities in the enhanced infrared techniques. The standard relationship between tropical cyclone "T-number", maximum sustained surface wind speed, and minimum sea-level pressure (Atkinson and Holliday, 1977) for the Pacific is shown in Table 2-2. For subtropical cyclones, intensity estimates are made using the Hebert and Poteat (1975) technique.

Table 2-2 MAXIMUM SUSTAINED WIND SPEED (KT) AS A FUNCTION OF DVORAK CURRENT AND FORECAST INTENSITY NUMBER AND MINIMUM SEA-LEVEL PRESSURE (MSLP)

T-NUMBER	WIND SPEED-KT	(M/SEC)	MSLP (MB) (PACIFIC)
0.0	<25	<(13)	- - - -
0.5	25	(13)	- - - -
1.0	25	(13)	- - - -
1.5	25	(13)	- - - -
2.0	30	(15)	1000
2.5	35	(18)	997
3.0	45	(23)	991
3.5	55	(28)	984
4.0	65	(33)	976
4.5	77	(40)	966
5.0	90	(46)	954
5.5	102	(53)	941
6.0	115	(59)	927
6.5	127	(65)	914
7.0	140	(72)	898
7.5	155	(80)	879
8.0	170	(87)	858

2.3.1 SATELLITE PLATFORM SUMMARY

Figure 2-2 shows the status of operational polar orbiting spacecraft. Three DMSP spacecraft were available to the tactical sites in 1993. Of these, F8 provided only vertically polarized 85 GHz channel SSM/I data after the loss of its Operational Line Scan (OLS) imaging system, F10's OLS functioned normally, but the eccentricity of its orbit presented gridding challenges, and F11 performed flawlessly. Of the four NOAA spacecraft, NOAA 9 remained in standby mode, while NOAA 10, 11 and 12 were operational. The NOAA 13 satellite which was launched 9 August failed shortly after launch.

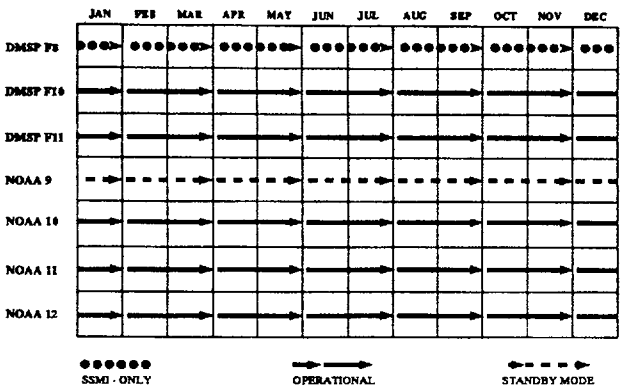


Figure 2-2 Polar orbiting spacecraft status for 1993

2.3.2 STATISTICAL SUMMARY

During 1993, fix and intensity information from the DMSP Network was the primary input to JTWC's warnings and post analyses. JTWC received at least 4520 satellite fixes — 3199 covered tropical cyclones in the western North Pacific, 96 in the North Indian Ocean, and 1225 in the Southern Hemisphere. The geostationary platform was the source of 73 percent of the fixes and 27 percent were from polar orbiters. A comparison of satellite fixes from all data sources with their corresponding best track positions is shown in Table 2-3.

2.3.3 APPLICATION OF NEW TECHNOLOGY

In April 1993, all tactical sites in the DMSP Network received the Mission Sensor Tactical Imaging Computer (MISTIC) II system upgrade, which allowed processing of the full resolution 12-bit SSM/I data and coregistration of the SSM/I and OLS. The Tropical Section at AFGWC, using its Satellite Data Handling System with 12-bit SSM/I capability, continued to provide the bulk of the SSM/I support to JTWC throughout the year.

2.3.4 FUTURE OF SATELLITE RECONNAISSANCE

Det 1 remains committed to maintaining, and at the same time improving the DMSP Network's support to the PACOM tropical cyclone warning system. Work continues to progress on the installation of new MARK IV-B tactical terminals in the western Pacific.

2.4 RADAR RECONNAISSANCE SUMMARY

Of the 38 significant tropical cyclones in the western North Pacific during 1993, 18 passed within range of land-based radar with sufficient precipitation and organization to be fixed. A total of 784 land-based radar fixes were logged at JTWC. The World Meteorological Organization (WMO) radar code defines three categories of accuracy: good [within 10 km (5 nm)], fair [within 10 - 30 km (5 - 16 nm)], and poor [within 30 - 50 km (16 - 27 nm)]. Of the 784 radar fixes encoded in this manner, 197 were good, 307 were fair, and 280 were poor. Excellent support from the radar network through timely and accurate radar fix positioning allowed JTWC to track and forecast tropical cyclone movement during even the most erratic track changes. In the Southern Hemisphere, 19 radar reports were logged for tropical cyclones. No fixes were received for the North Indian Ocean.

The weather radar for Guam, which was destroyed in August 1992 by Typhoon Omar was restored, and improved, in February 1993, with the installation of the Andersen AFB NEXRAD Doppler radar.

2.5 TROPICAL CYCLONE FIX DATA

Table 2-4a delineates the number of fixes per platform for each individual tropical cyc-

lone for the western North Pacific. Totals and percentages are also indicated. Similar information is provided for the North Indian Ocean in Table 2-4b, and for the South Pacific and South Indian Oceans in Table 2-4c.

Table 2-3 MEAN DEVIATION(NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS (NUMBER OF CASES IN PARENTHESES)

NORTHWEST PACIFIC OCEAN

PCN	1982-1992 AVERAGE		1993 AVERAGE	
1&2	13.8	(6108)	13.9	(513)
3&4	21.9	(6398)	30.0	(434)
5&6	37.1	(13668)	39.7	(2252)
Totals	27.9	(26174)	34.2	(3199)

NORTH INDIAN OCEAN

PCN	1982-1992 AVERAGE		1993 AVERAGE	
1&2	13.3	(167)	18.5	(4)
3&4	30.9	(117)	66.1	(9)
5&6	38.1	(1335)	43.9	(83)
Totals	35.1	(1639)	45.4	(96)

WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEAN

PCN	1982-1992 AVERAGE		1993 AVERAGE	
1&2	15.9	(1971)	13.8	(248)
3&4	26.9	(1668)	19.6	(220)
5&6	36.1	(7947)	33.2	(757)
Totals	31.3	(11586)	26.8	(1225)

Table 2-4a 1993 NORTHWEST PACIFIC OCEAN FIX PLATFORM SUMMARY

TROPICAL CYCLONE			SATELLITE	RADAR	SYNOPTIC	AIRCRAFT	TOTAL
01W	TD		23	0	0	0	23
02W	TS	Irma	106	0	0	0	106
03W	TD		28	0	0	0	28
04W	TD		105	0	0	0	105
05W	TS	Jack	79	0	0	0	79
06W	STY	Koryn	155	10	4	0	169
07W	TD		42	0	0	0	42
08W	TY	Lewis	91	6	24	0	121
09W	TS	Marian	62	0	11	0	73
10W	TY	Nathan	96	22	0	0	118
11W	TS	Ofelia	45	57	0	1	103
12W	TY	Percy	51	51	0	0	102
13W	TY	Robyn	139	88	0	5	232
14W	TY	Steve	92	6	0	0	98
15W	TD		33	0	0	0	33
16W	TY	Tasha	89	26	0	0	115
17W	TY	Vernon	90	55	0	0	145
18W	TS	Winona	89	0	1	0	90
19W	STY	Yancy	107	166	0	0	273
01C	TY	Keoni	87	0	0	0	87
20W	TS	Zola	66	74	3	0	143
21W	TY	Abe	98	100	0	0	198
22W	TY	Becky	56	16	0	0	72
23W	TY	Cecil	75	0	0	0	75
24W	TY	Dot	23	0	0	0	23
25W	STY	Ed	117	38	0	0	155
26W	TY	Flo	96	13	3	0	112
27W	TS	Gene	60	0	0	0	60
28W*	TD		57	15	0	0	72
29W	TS	Hattie	84	0	0	0	84
30W	TY	Ira	118	13	0	0	131
31W	TS	Jeane	95	20	0	0	115
32W	TD		53	0	0	0	53
33W	TD		34	0	0	0	34
34W	TY	Kyle	66	0	0	0	66
35W	TY	Lola	105	8	0	0	113
36W	TY	Manny	158	0	0	0	158
37W	TY	Nell	114	0	0	0	114
		Totals	3084	784	46	6	3920
Percentage of Total			79%	20%	1%	<1%	100%

* Regenerated

Table 2-4b 1993 NORTH INDIAN OCEAN FIX PLATFORM SUMMARY

TROPICAL CYCLONE	SATELLITE	RADAR	SYNOPTIC	TOTAL
01A	23	0	0	23
02B	76	0	0	76
Totals	99	0	0	99
Percentage of Total	100%	0%	0%	100%

Table 2-4c 1993 SOUTH PACIFIC AND SOUTH INDIAN OCEANS FIX PLATFORM SUMMARY

TROPICAL CYCLONE		SATELLITE	RADAR	SYNOPTIC	AIRCRAFT	TOTAL
01S	Aviona	48	0	0	0	48
02S	Babie	13	0	0	0	13
03P	Joni	107	0	0	0	107
04S	- - - -	17	0	0	0	17
05S	Ken	66	0	0	0	66
06P	Nina	152	10	0	0	162
07P	Kina	123	0	0	0	123
08P	- - - -	5	0	0	0	5
09P	- - - -	12	0	0	0	12
10S	Colina	40	0	0	0	40
11S	Dessilia	7	0	0	0	7
12S	Edwina	67	0	0	0	67
13S	Lena	69	0	0	0	69
14P	- - - -*	64	0	0	0	64
15P	Lin	38	0	0	0	38
16P	Oliver	120	9	0	1	130
17P	Mick	32	0	1	0	33
18P	Nisha	43	0	0	0	43
19S	Finella	20	0	0	0	20
20P	Oli	33	0	5	0	38
21P	Polly	77	0	0	0	77
22P	Roger	88	0	0	0	88
23P	Prema	79	0	0	0	79
24S	Jourdanne	61	0	0	0	61
25S	Monty	39	0	0	0	39
26S	Konita	48	0	0	0	48
27P	Adel	42	0	0	0	42
	Totals	1510	19	6	1	1536
	Percentage of Total	98 %	1 %	<1 %	<1 %	100 %

* Regenerated

3. SUMMARY OF WESTERN NORTH PACIFIC AND NORTH INDIAN OCEAN TROPICAL CYCLONES

3.1 WESTERN NORTH PACIFIC OCEAN TROPICAL CYCLONES

The year of 1993 included 21 typhoons (including 3 super typhoons), 9 tropical storms and 8 tropical depressions (Table 3-1). The calendar year total of 38 significant tropical cyclones in the western North Pacific (8 over the average) was the highest since 1967 when there were 41 (Table 3-2). The high number (8) of tropical cyclones reaching only tropical-depression intensity has not been equaled since 1966 which may be due, in part, to a concerted effort to identify significant tropical cyclones early in their life cycle. The year's total of three super typhoons was one short of the 24-year (1970-1993) average for western North Pacific super typhoons (Figure 3-1). The year's total of 30 named tropical cyclones was two above the 34-year average (1960-1993) (Figure 3-2). Thirty-five of the 38 tropical cyclones in the western North Pacific during 1993 originated in

Table 3-1 WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES FOR 1993

TROPICAL CYCLONE		PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	ESTIMATED MAXIMUM SURFACE WINDS KT (M/SEC)	ESTIMATED MSLP (MB)
01W	TD	01 MAR - 02 MAR	5	25 (13)	1002
02W	TS IRMA	10 MAR - 17 MAR	27	55 (28)	984
03W	TD	12 APR - 14 APR	5	25 (13)	1002
04W	TD	20 APR - 27 APR	31	30 (15)	1000
05W	TS JACK	17 MAY - 22 MAY	20	35 (18)	997
06W	STY KORYN	15 JUN - 29 JUN	51	130 (67)	910
07W	TD	17 JUN - 20 JUN	12	30 (15)	1000
08W	TY LEWIS	07 JUL - 12 JUL	23	85 (44)	958
09W	TS MARIAN	13 JUL - 17 JUL	16	45 (23)	991
10W	TY NATHAN	19 JUL - 25 JUL	25	70 (36)	972
11W	TS OFELIA	25 JUL - 25 JUL	12	45 (23)	991
12W	TY PERCY	27 JUL - 30 JUL	12	65 (33)	976
13W	TY ROBYN	01 AUG - 10 AUG	38	120 (62)	922
14W	TY STEVE	06 AUG - 12 AUG	28	65 (33)	976
15W	TD	13 AUG - 14 AUG	6	25 (13)	1002
16W	TY TASHA	15 AUG - 22 AUG	29	80 (41)	963
17W	TY VERNON	21 AUG - 28 AUG	26	80 (41)	963
18W	TS WINONA	22 AUG - 29 AUG	30	45 (23)	991
19W	STY YANCY	29 AUG - 04 SEP	26	130 (67)	910
01C	TY KEONI	20 AUG - 28 AUG	35	100 (51)	944
20W	TS ZOLA	05 SEP - 09 SEP	16	55 (28)	984
21W	TY ABE	09 SEP - 15 SEP	25	110 (57)	933
22W	TY BECKY	14 SEP - 17 SEP	13	65 (33)	976
23W	TY CECIL	22 SEP - 27 SEP	21	100 (51)	944
24W	TY DOT	23 SEP - 27 SEP	18	80 (41)	963
25W	STY ED	30 SEP - 08 OCT	34	140 (72)	898
26W	TY FLO	01 OCT - 08 OCT	30	70 (36)	972
27W	TS GENE	06 OCT - 10 OCT	15	35 (18)	997
28W	TD	07-09 OCT/12-13 OCT	13	25 (13)	1002
29W	TS HATTIE	19 OCT - 25 OCT	23	50 (26)	991
30W	TY IRA	27 OCT - 05 NOV	34	120 (62)	922
31W	TS JEANA	05 NOV - 12 NOV	30	50 (26)	987
32W	TD	18 NOV - 19 NOV	5	25 (13)	1002
33W	TD	18 NOV - 19 NOV	3	25 (13)	1002
34W	TY KYLE	19 NOV - 24 NOV	19	95 (49)	949
35W	TY LOLA	02 DEC - 09 DEC	30	105 (54)	938
36W	TY MANNY	03 DEC - 15 DEC	50	120 (62)	922
37W	TY NELL	23 DEC - 28 DEC	17	70 (36)	972
			TOTAL: 853		

Table 3-2 DISTRIBUTION OF WESTERN NORTH PACIFIC TROPICAL CYCLONES FOR 1959 - 1993

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1959	0	1	1	1	0	1	3	8	9	3	2	2	31
	000	010	010	100	000	001	111	512	423	210	200	200	17 7 7
1960	1	0	1	1	1	3	3	9	5	4	1	1	30
	001	000	001	100	010	210	210	810	041	400	100	100	19 8 3
1961	1	1	1	1	4	6	5	7	6	7	2	1	42
	010	010	100	010	211	114	320	313	510	322	101	100	20 11 11
1962	0	1	0	1	3	0	8	8	7	5	4	2	39
	000	010	000	100	201	000	512	701	313	311	301	020	24 6 9
1963	0	0	1	1	0	4	5	4	4	6	0	3	28
	000	000	001	100	000	310	311	301	220	510	000	210	19 6 3
1964	0	0	0	0	3	2	8	8	8	7	6	2	44
	000	000	000	000	201	200	611	350	521	331	420	101	26 13 5
1965	2	2	1	1	2	4	6	7	9	3	2	1	40
	110	020	010	100	101	310	411	322	531	201	110	010	21 13 6
1966	0	0	0	1	2	1	4	9	10	4	5	2	38
	000	000	000	100	200	100	310	531	532	112	122	101	20 10 8
1967	1	0	2	1	1	1	8	10	8	4	4	1	41
	010	000	110	100	010	100	332	343	530	211	400	010	20 15 6
1968	0	1	0	1	0	4	3	8	4	6	4	0	31
	000	001	000	100	000	202	120	341	400	510	400	000	20 7 4
1969	1	0	1	1	0	0	3	3	6	5	2	1	23
	100	000	010	100	000	000	210	210	204	410	110	010	13 6 4
1970	0	1	0	0	0	2	3	7	4	6	4	0	27
	000	100	000	000	000	110	021	421	220	321	130	000	12 12 3
1971	1	0	1	2	5	2	8	5	7	4	2	0	37
	010	000	010	200	230	200	620	311	511	310	110	000	24 11 2
1972	1	0	1	0	0	4	5	5	6	5	2	3	32
	100	000	001	000	000	220	410	320	411	410	200	210	22 8 2
1973	0	0	0	0	0	0	7	6	3	4	3	0	23
	000	000	000	000	000	000	430	231	201	400	030	000	12 9 2
1974	1	0	1	1	1	4	5	7	5	4	4	2	35
	010	000	010	010	100	121	230	232	320	400	220	020	15 17 3
1975	1	0	0	1	0	0	1	6	5	6	3	2	25
	100	000	000	001	000	000	010	411	410	321	210	002	14 6 5
1976	1	1	0	2	2	2	4	4	5	0	2	2	25
	100	010	000	110	200	200	220	130	410	000	110	020	14 11 0
1977	0	0	1	0	1	1	4	2	5	4	2	1	21
	000	000	010	000	001	010	301	020	230	310	200	100	11 8 2
1978	1	0	0	1	0	3	4	8	4	7	4	0	32
	010	000	000	100	000	030	310	341	310	412	121	000	15 13 4
1979	1	0	1	1	2	0	5	4	6	3	2	3	28
	100	000	100	100	011	000	221	202	330	210	110	111	14 9 5
1980	0	0	1	1	4	1	5	3	7	4	1	1	28
	000	000	001	010	220	010	311	201	511	220	100	010	15 9 4
1981	0	0	1	1	1	2	5	8	4	2	3	2	29
	000	000	100	010	010	200	230	251	400	110	210	200	16 12 1
1982	0	0	3	0	1	3	4	5	6	4	1	1	28
	000	000	210	000	100	120	220	500	321	301	100	100	19 7 2
1983	0	0	0	0	0	1	3	6	3	5	5	2	25
	000	000	000	000	000	010	300	231	111	320	320	020	12 11 2
1984	0	0	0	0	0	2	5	7	4	8	3	1	30
	000	000	000	000	000	020	410	232	130	521	300	100	16 11 3
1985	2	0	0	0	1	3	1	7	5	5	1	2	27
	020	000	000	000	100	201	100	520	320	410	010	110	17 9 1
1986	0	1	0	1	2	2	2	5	2	5	4	3	27
	000	100	000	100	110	110	200	410	200	320	220	210	19 8 0
1987	1	0	0	1	0	2	4	4	7	2	3	1	25
	100	000	000	010	000	110	400	310	511	200	120	100	18 6 1

TABLE CONTINUED ON TOP OF NEXT PAGE

CONTINUED FROM PREVIOUS PAGE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1988	1	0	0	0	1	3	2	5	8	4	2	1	27
	100	000	000	000	100	111	110	230	260	400	200	010	14 12 1
1989	1	0	0	1	2	2	6	8	4	6	3	2	35
	010	000	000	100	200	110	231	332	220	600	300	101	21 10 4
1990	1	0	0	1	2	4	4	5	5	5	4	1	31
	100	000	000	010	110	211	220	500	410	230	310	100	21 9 1
1991	0	0	2	1	1	1	4	8	6	3	6	0	32
	000	000	110	010	100	100	400	332	420	300	330	000	20 10 2
1992	1	1	0	0	0	3	4	8	5	6	5	0	33
	100	010	000	000	000	210	220	440	410	510	311	000	21 11 1
1993	0	0	2	2	1	2	5	8	5	6	4	3	38
	000	000	011	002	010	101	320	611	410	321	112	300	21 9 8
(1959-1993)													
MEAN	0.6	0.3	0.6	0.8	1.2	2.1	4.5	6.3	5.6	4.6	3.0	1.4	31.1
CASES	20	10	22	27	43	75	156	222	197	162	105	49	1088

The criteria used in Table 3-2 are as follows:

1) If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month.

2) If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

3) If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

TABLE 3-2 LEGEND

Total for the month/year → 38

Typhoons → 21

Tropical Storms → 9

Tropical Depressions → 8

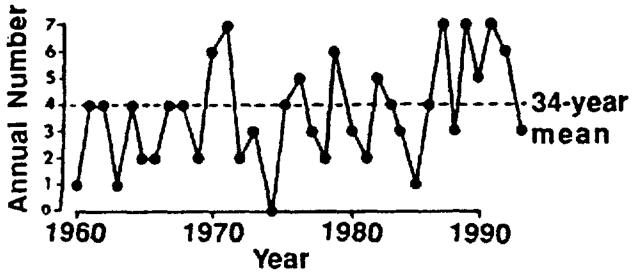


Figure 3-1 Number of western North Pacific super typhoons (1960-1993)

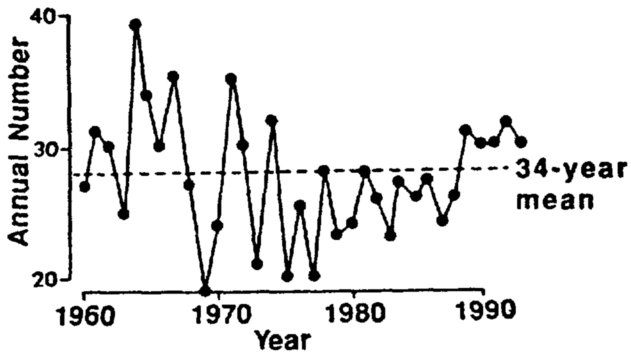


Figure 3-2 Tropical cyclones of tropical storm or greater intensity in the western North Pacific (1960-1993)

the low-level monsoon trough or near-equatorial trough. Two — Ofelia (11W) and Percy (12W) — formed in the peripheral cloud band of a monsoon gyre; and one — Keoni (01C) — formed in the trade-wind trough of the central Pacific. There were no tropical cyclones that formed in subtropical latitudes in direct association with cyclonic cells in the tropical upper-tropospheric trough (TUTT) during this season.

El Niño conditions prevailed in the tropical Pacific during most of 1993: the sea surface temperature (SST) of the eastern equatorial Pacific was consistently warmer than normal, and the Southern Oscillation Index (SOI) (Climate Analysis Center, 1993) remained negative until very late in the year when it returned to near normal (Figure 3-3a). By comparison, the evolution of the SST and SOI in 1993 was somewhat similar to a composite of several past El Niño events (Figure 3-3b) (Rasmusson and

Carpenter, 1982). During January through October of 1993, the low-level wind of the tropical western Pacific featured an eastward displacement — with respect to climatology — of monsoonal westerlies (Figure 3-4). This wind pattern is commonly observed during occurrences of El Niño. In addition to the eastward displacement of monsoonal westerlies in low latitudes, the low-level westerly wind flow associated with the Mei-yu (Chinese for: plum rains) front was more persistent than normal and lasted into August (Figure 3-4). The Mei-yu front is a semi-permanent low-pressure trough of the east Asian subtropics during spring and early summer which extends eastward from near Taiwan into the ocean area southeast of Japan. The lingering Mei-yu front's associated cloud band, and the impact of several typhoons, resulted in a very cool and wet summer for Japan.

With the anomalous eastward push of monsoonal westerlies, many of the year's tropical cyclones formed east of 145°E in the eastern Caroline and Marshall islands (Figure 3-5a), and the mean genesis location of all tropical cyclones during 1993 was south and east of normal (Figure 3-5b) — yet another characteristic of El Niño years. In the 24-year period, 1970-1993, the mean genesis location for 1993 was the southernmost of record (Figure 3-5b). The fact that eight of the year's first nine tropical cyclones formed south of 10°N certainly contributed to pushing the mean genesis location southward, as did the complete lack of genesis of tropical cyclones north of 20°N and east of 160°E, a region more favored for tropical cyclogenesis during non-El Niño years (Lander, 1994). The 1993 Atlantic Hurricane Season also featured this peculiar tendency for storms to form and remain at very low latitudes, impacting Venezuela, Nicaragua and Honduras.

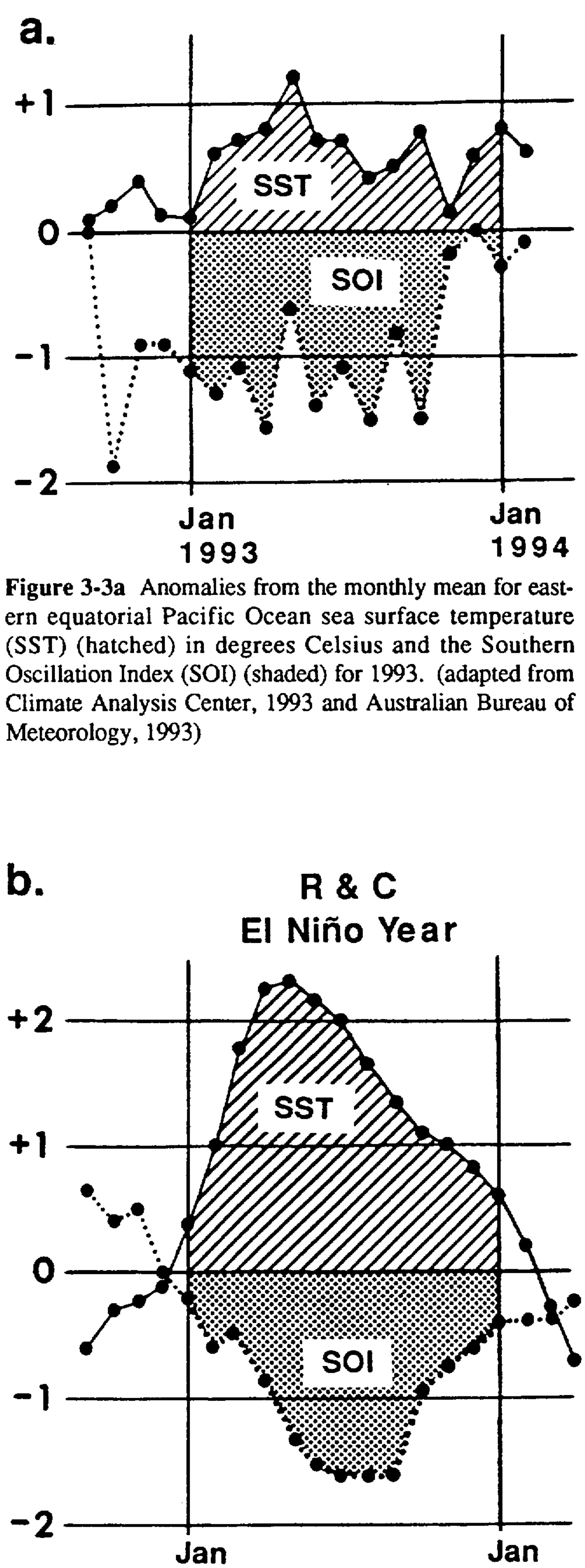


Figure 3-3a Anomalies from the monthly mean for eastern equatorial Pacific Ocean sea surface temperature (SST) (hatched) in degrees Celsius and the Southern Oscillation Index (SOI) (shaded) for 1993. (adapted from Climate Analysis Center, 1993 and Australian Bureau of Meteorology, 1993)

Figure 3-3b Composites of the eastern equatorial Pacific SST anormaly (hatched), and of the SOI (shaded), for six El Nino events (1951, 1953, 1957, 1965, 1969, 1972) [after Rasmusson and Carpenter (R&C), 1982].

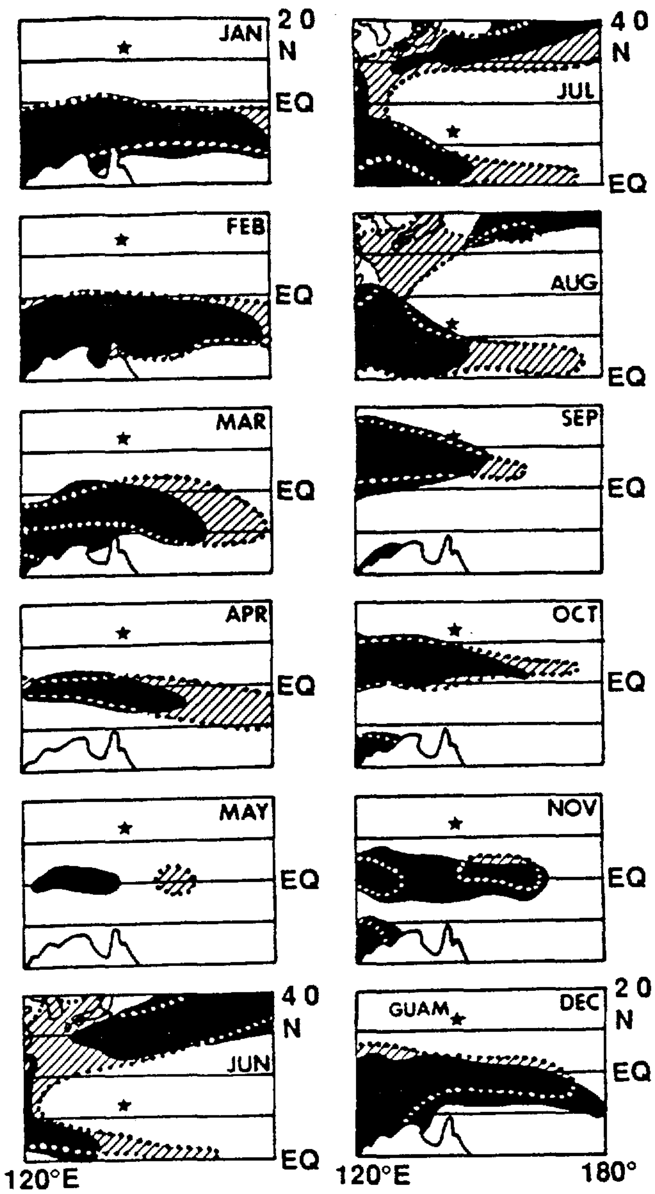


Figure 3-4 Comparison between climatological (black) and analyzed (hatched) mean monthly winds with a westerly component for the western North Pacific in 1993. For June, July, and August the area of coverage is shifted northward to include the subtropics of the North Pacific. For reference, the star indicates the location of Guam. The outline of Australia appears in the lower left of each panel except for June, July, and August where the Korean Peninsula and Japan appear in the upper left. The climatology is adapted from Sadler *et al.*, 1987. The 1993 monthly mean winds were adapted from Australian Bureau of Meteorology, 1993.

Partly as a consequence of many low-latitude (south of 10°N) formations and subsequent westward tracks, the Philippine Islands and Vietnam were impacted by a large number of tropical cyclones. The 18 tropical cyclones of the western North Pacific during 1993 making landfall in the Philippine Islands was a record.

Low-level westerly wind flow along the equator, bounded by near-equatorial troughs in the Northern Hemisphere and Southern Hemisphere, was a persistent wind pattern (hereafter to be referred to as the twin-trough pattern) in the tropical western Pacific from late February through mid-July 1993. This wind pattern is ideal for the development of equatorial westerly wind bursts (Luther et al., 1983; Keen, 1988), and also for the formation of tropical cyclone twins symmetrical with respect to the equator (Dean, 1954; Keen, 1982; Lander, 1990) (see Figure 3-6a). This wind pattern may also feature the simultaneous occurrence of tropical cyclones in both the northern and southern hemispheres which are not symmetrical with respect to the equator, and which may not be at the same stage of development (Figure 3-6b). According to Lander (1990), an equatorial westerly wind burst is a necessary, but not always sufficient, precondition for the formation of tropical cyclone twins.

The first six tropical cyclones of 1993 — Tropical Depression 01W, Irma (02W), Tropical Depression 03W, Tropical Depression 04W, Jack (05W), and Koryn (06W) — all formed in the near-equatorial trough in a large-scale wind and cloud pattern similar to Figure 3-6a or 3-6b. During March, the first named tropical cyclone of the year in the western North Pacific, Irma (02W), formed in association with a westerly wind burst; and, along with Roger (22P), was a classical case of tropical cyclone twins symmetrical with respect to the equator. During April, Tropical Depression 04W formed in association with another equatorial westerly wind burst, and was accompanied by a southern hemisphere twin that didn't mature. Tropical Depression

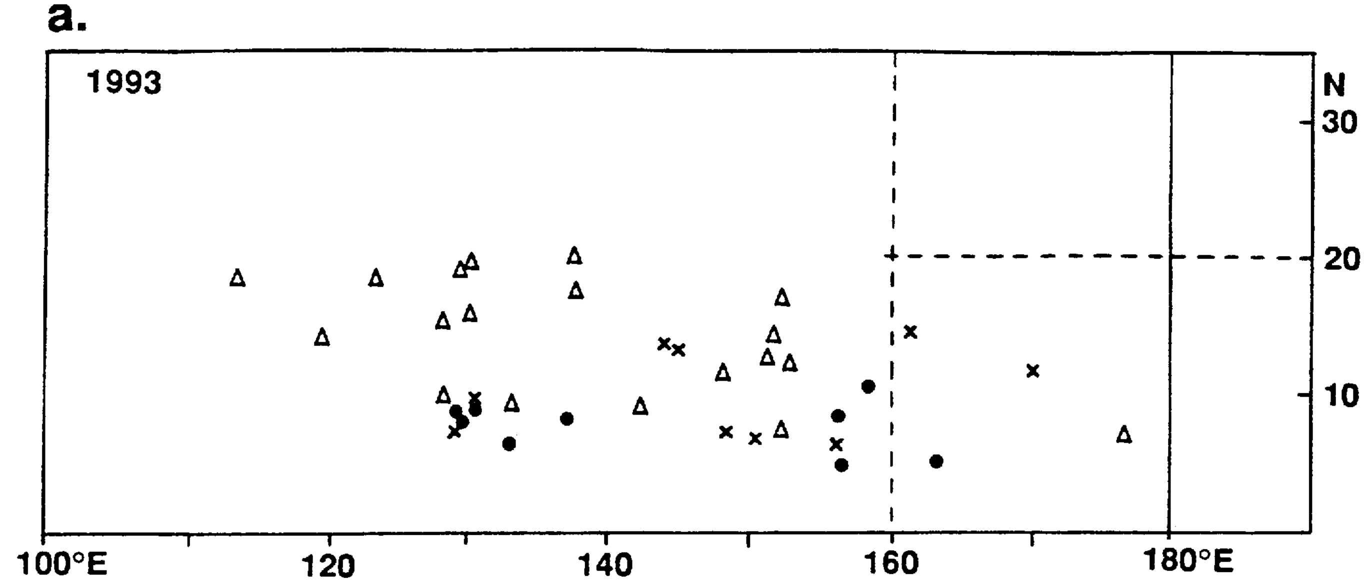


Figure 3-5a Point of formation of significant tropical cyclones in 1993 as indicated by the initial intensity of 25 kt (13 m/sec) on the best track. The symbols indicate: solid dots = 01 January to 15 July; open triangles = 16 July to 15 October; and, X = 16 October to 31 December.

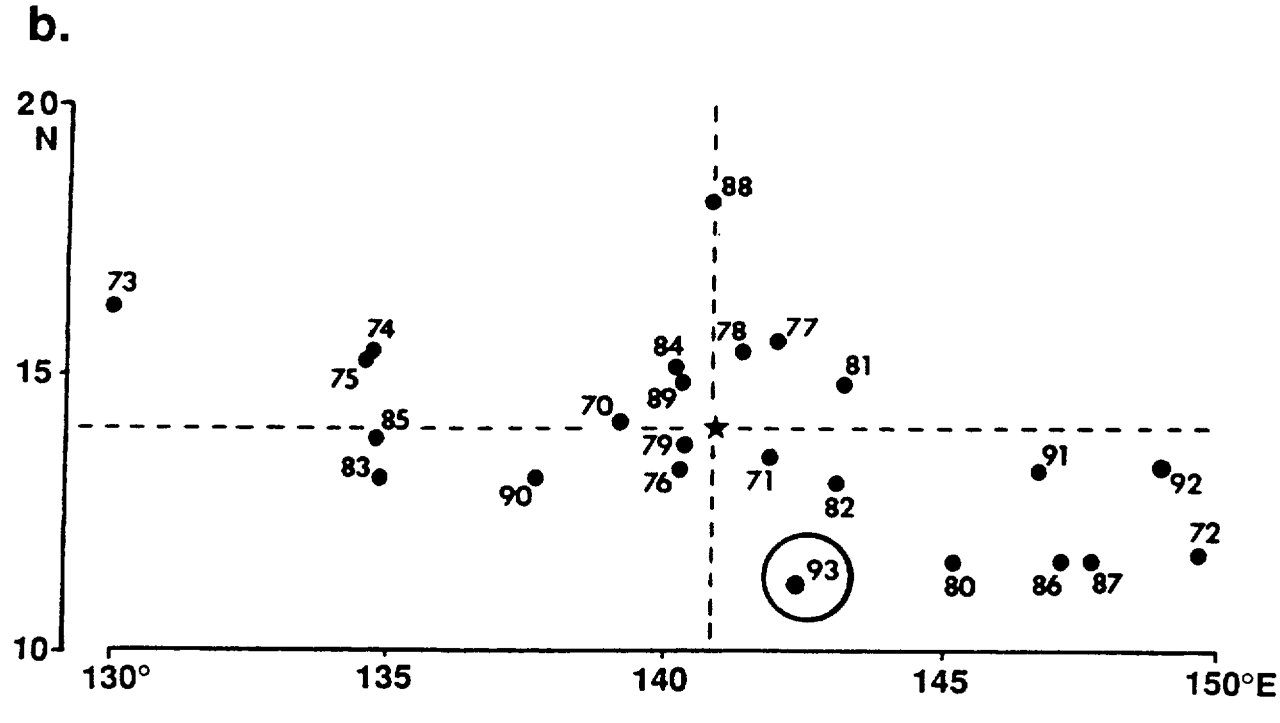


Figure 3-5b Mean annual genesis locations for the period 1970-1993. The 1993's circled location is the southernmost for the 24 years. The star lies at the intersection of the 24-year average latitude and longitude of genisis. For statistical puposes, genesis is defined as the first 25 kt (13 m/sec) intensity on the best track.

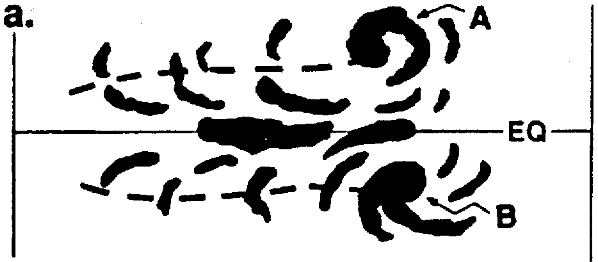


Figure 3-6a Twin-trough pattern associated with a westerly wind burst with tropical cyclones, at points A and B, forming symmetrically with respect to the equator. The axes of the near-equatorial troughs are represented by dashed lines..

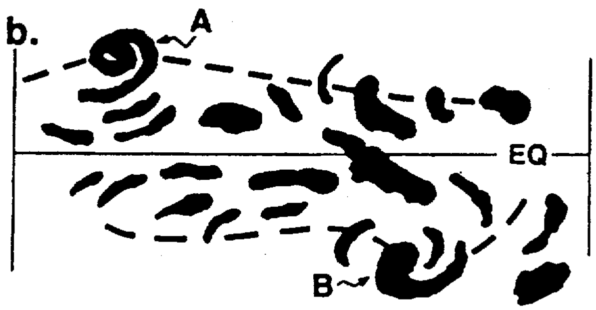


Figure 3-6b Twin-trough pattern with tropical cyclones at points A and B forming without symmetry with respect to the equator.

04W was remarkable for its long westward track, and for its inability to intensify beyond 30 kt (15 m/sec). For several days, the depression was forecast to intensify into a tropical storm but it never did. Jack (05W) formed in the near-equatorial trough of the Northern Hemisphere a few days after Adel (27P) had formed in the twin near-equatorial trough of the Southern Hemisphere in a large-scale low-level flow pattern similar to that shown in Figure 3-6b. During mid June, Koryn (06W) formed at a very low latitude (4°N) in a low-level flow pattern which, yet again, featured equatorial westerlies bounded by twin near-equatorial troughs.

During late June, the large-scale flow pattern, which had resembled the flow patterns shown in Figure 3-6 a and b nearly continuously since February, changed so as to resemble more closely the long-term mean wind field. In this new regime, a weak monsoon trough extended from southeast Asia into the Philippine Sea, and from there eastward into the Caroline Islands. The three tropical cyclones following Typhoon Koryn — Tropical Depression 07W, Lewis (08W), and Marian (09W) — generated in this monsoon trough (see Figure 3-7).

Nathan (10W), formed in the eastern Caroline Islands, was the last tropical cyclone in this monsoon trough as the next major readjustment of the large-scale flow pattern in the tropics of the western North Pacific occurred in late July with the formation of a monsoon gyre in the Philippine Sea. As Nathan moved west-northwestward, a large monsoonal cloud band formed in the Philippine Sea in association with lowering sea-level pressure there. Nathan turned northward as it neared the monsoonal cloud band. This cloud band then became oriented SW-NE and was collocated with a band of 25-35 kt (13-18 m/sec) low-level southwesterly winds on the southeastern periphery of a large low-pressure area, a monsoon gyre, over the Philippine Sea. Nathan accelerated northward to a landfall on Japan. Subsequently, as the monsoon gyre moved steadily westward, two very small tropical cyclones, Ofelia(11W) and Percy (12W), formed in quick succession at the northern end of the monsoon cloud band of the monsoon gyre and moved on north-oriented tracks over southwestern Japan. By the last day of July, the monsoon gyre had been absorbed into the large-scale low-pressure area over eastern Asia.

Also during the last week of July, as the low-pressure area associated with the monsoon gyre moved westward toward east Asia, pressures began to fall in Micronesia, and the monsoon trough extended from the Caroline Islands eastward to the international date line. During the first week of August (Figure 3-8), Typhoons Robyn (13W) and Steve (14W) formed in this monsoon trough. Robyn became a large-sized typhoon which recurved and hit southwestern Japan. During the last two weeks of August, Hurricane Keoni (01C) moved across the

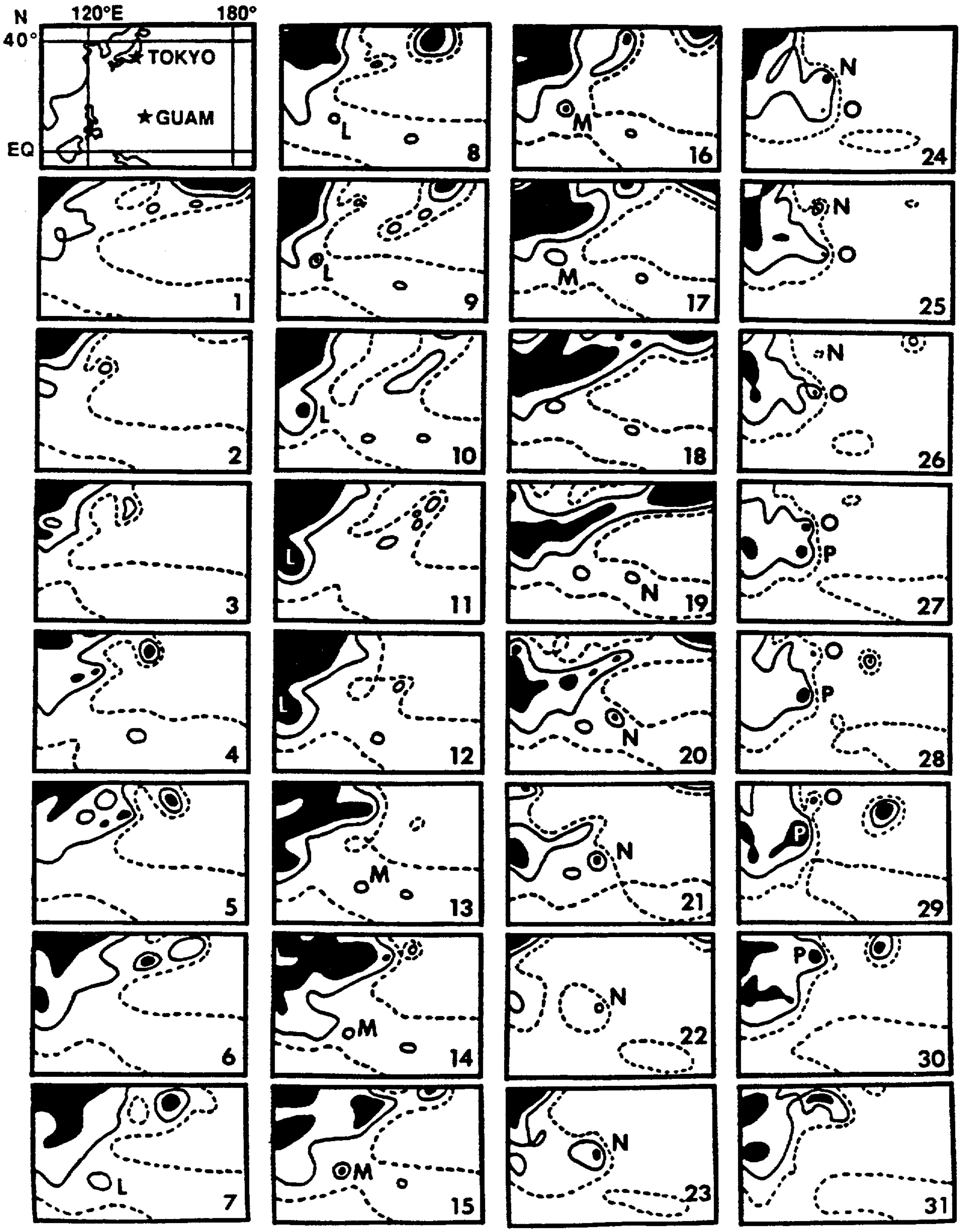


Figure 3-7 Western North Pacific sea-level pressure analyses for July 1993. Map panels are for 0600Z for the date indicated in the lower right of each panel. A geographic reference appears as the upper left panel. Contours (01-21 July): outer dashed line = 1010 mb; solid line = 1008 mb; black ≤ 1004 mb. Contours (22-31 July): outer dashed line = 1008 mb; solid line = 1006 mb; and black area ≤ 1002 mb. Named tropical cyclones: L = Lewis (08W), M = Marian (09W), N = Nathan (10W), O = Ofelia (11W), and P = Percy (12W).

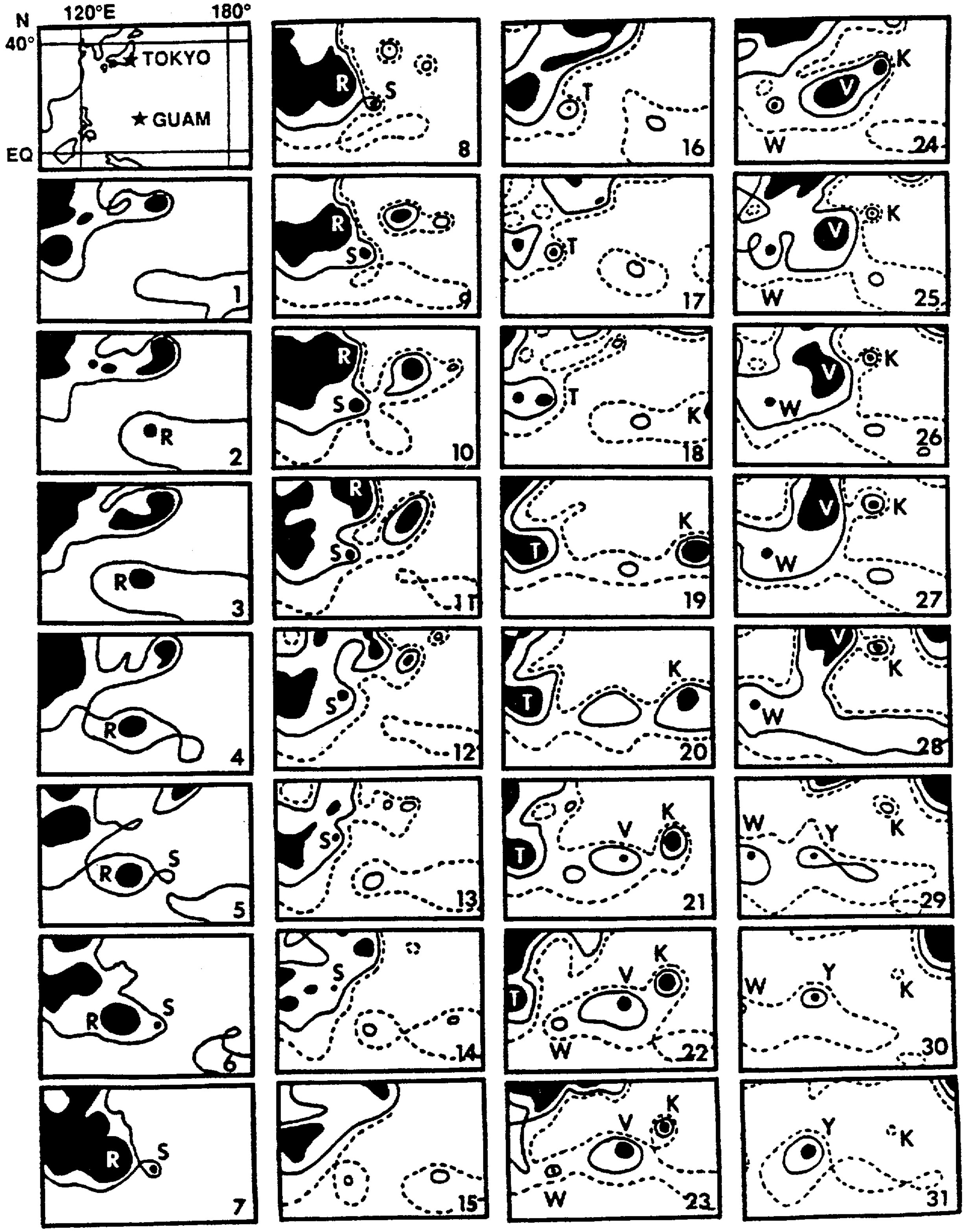


Figure 3-8 Western North Pacific sea-level pressure analyses for August 1993. Map panels are for 0600Z for the date indicated in the lower right of each panel. A geographic reference appears as the upper left panel. Contours: outer dashed line = 1010 mb; solid line = 1008 mb; black ≤ 1004 mb. Named tropical cyclones: R = Robyn (13W), S = Steve (14W), T = Tasha (16W), K = Keoni (01C), and V = Vernon (17W), W = Winona (18W), Y = Yancy.

international date line from the central Pacific into the western Pacific — was renamed Typhoon Keoni — and meandered for two weeks over subtropical waters north of Wake Island. During the last two weeks of August and into the first week of September, the monsoon trough of the western North Pacific became very active as seven tropical cyclones — Tasha (16W), Vernon (17W), Winona (18W), Yancy (19W), Zola (20W), Abe (21W) and Becky (22W) — formed in it. Three of these tropical cyclones — Vernon (17W), Yancy (19W), and Zola (20W) — made landfall in Japan. During the last week of July through the first week of September, a concentrated assault of Japan by tropical cyclones took place. Seven of the period's 12 tropical cyclones, beginning with Nathan (10W) during the last week of July and ending with Zola (20W) during the first week of September, made landfall there.

Five of seven tropical cyclones occurring from late September to midOctober — Cecil (23W), Ed (25W), Flo (26W), Gene (27W) and Hattie (29W) — recurved into the mid-latitudes of the North Pacific well offshore of Japan. After Hattie, which formed as a very large monsoon depression then recurved into mid-latitudes in late October, all subsequent tropical cyclones formed at low-latitude (near or south of 10°N) and traveled on westward tracks which kept them in tropical latitudes. Six of the final eight tropical cyclones of 1993, beginning with Ira (30W) and ending with Nell (37W), made landfall in the Philippine Islands.

In early November, three tropical cyclones — Jeana (31W), Tropical Depression 32W, and Tropical Depression 33W — developed, but failed to mature. Jeana reached 50 kt (26 m/sec) for only a brief time after recurvature. Jeana was one of a small subset of all tropical cyclones that reached peak intensity after recurvature. Tropical Depression 32W and Tropical Depression 33W both had long histories as disturbances. Four Tropical Cyclone Formation Alerts were issued on the disturbance that eventually became Tropical Depression 32W. All subsequent tropical cyclones — Kyle (34W), Lola (35W), Manny (36W), and Nell (37W) — became typhoons. The last tropical cyclone of November, Kyle (34W) developed just to the northeast of Tropical Depression 32W. Both systems moved into the southern Philippine Islands in tandem. Tropical Depression 32W dissipated there. Kyle crossed the Philippine Islands into the South China Sea, moved toward Vietnam, and rapidly intensified.

During December, Lola (35W) formed in an active near-equatorial trough that ultimately produced a series of three late-season typhoons — Lola (35W), Manny (36W) and Nell (37W). After developing in the western Marshall Islands, Lola slowly intensified, and over a week later, slammed into the heavily populated Bicol region of southern Luzon. Upon leaving the Philippine Islands, Lola headed toward the southwest, rapidly re-intensified — a rare event in the South China Sea — and crashed into southern Vietnam. Three days after Lola developed, Manny began to form in the eastern Caroline Islands along the axis of the near-equatorial trough. Like Lola, Manny raced across the Micronesian Islands at 20 kt (35 km/hr) and slowly intensified. Unlike Lola, Manny slowed to the east of Luzon, and appeared to be very close to recurving; instead it executed an anticyclonic loop, then came out of the loop on a southwestward track and rapidly intensified en route to the Philippine Islands. Manny weakened to a weak tropical storm in the South China Sea, moved to the southern Gulf of Thailand, and dissipated over the Malay Peninsula. A few days later, Nell (37W) began to develop in the eastern Caroline Islands, about 300 nm (555 km) west of where Manny had developed. Nell crossed the Philippine Sea at an average speed of 15 kt (28 km/hr), slowly intensifying. Fortunately, Nell was a very small typhoon when it crashed into northern Mindanao, turned to the northwest, and

crossed the Visayan Islands of Bohol, Cebu, Iloilo, and Panay. After exiting the Philippine Islands, Nell ran into strong upper-level shear, turned to the southwest, and dissipated over water in the southeastern South China Sea. The long westward tracks of the late-season tropical cyclones were associated with an anchored long-wave trough over western and central China and a high zonal index of the mid-latitude westerlies. The western North Pacific basin continued to be active right up to the end of the calendar year 1993; on 30 December 1993, Nell (37W) — the last of three Typhoons in December — dissipated in the South China Sea.

In summary, an illustration of all the tropical cyclone activity in the western North Pacific and North Indian Oceans is provided in Figure 3-9. Table 3-3 includes: a climatology of typhoons, tropical storms and typhoons for the western North Pacific for the period 1945-1959 and 1960-1993; and summary of warning days. Table 3-4 is a summary of the TCFA's for the Western North Pacific for 1976-1993. Composite best tracks for the North West Pacific Ocean tropical cyclones are provided for the periods: 1 January to 26 July (Figure 3-10), 24 July to 10 September (Figure 3-11), 7 September to 5 November (Figure 3-12), and 7 November to 31 December (Figure 3-13).

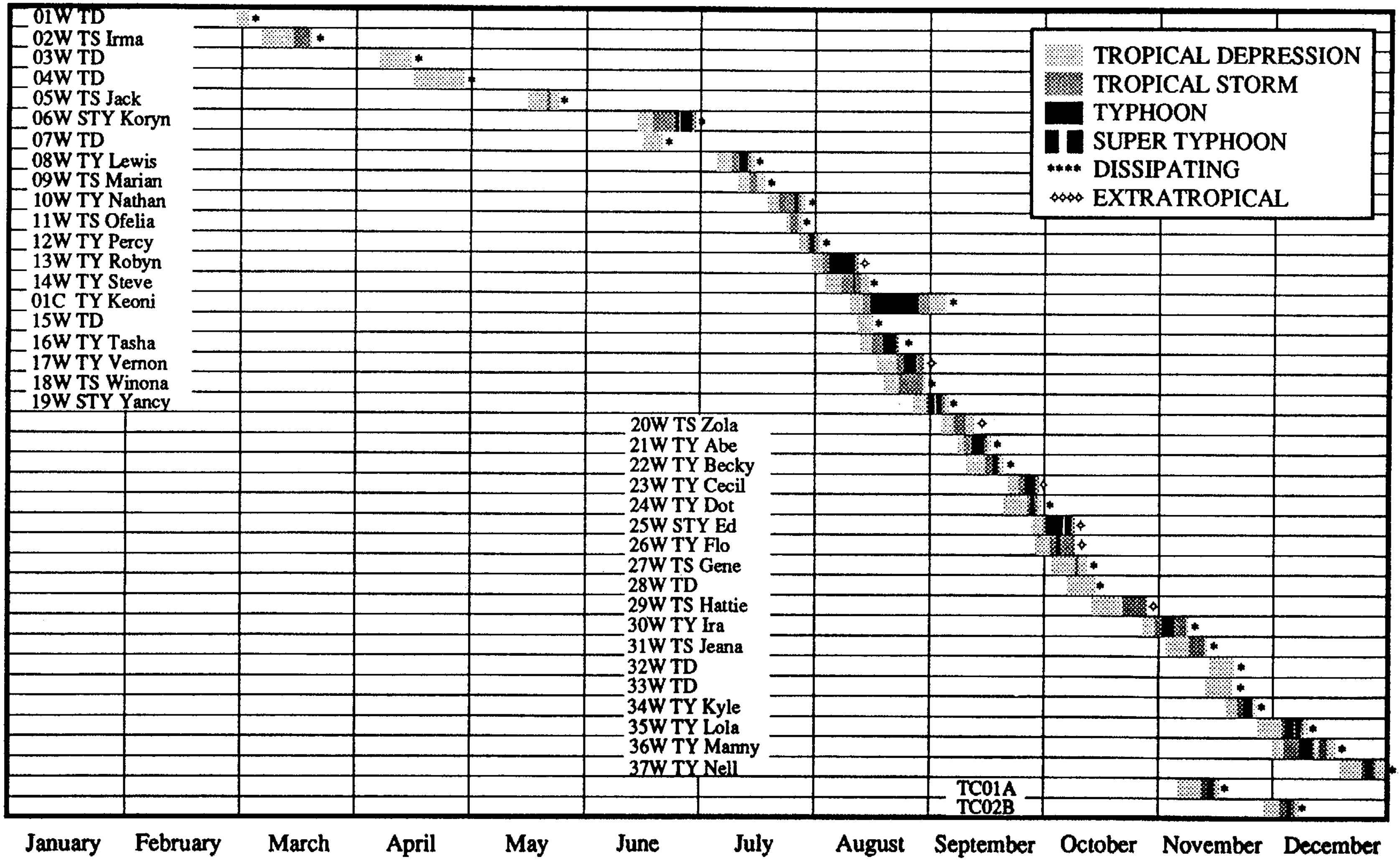


Figure 3-9 Chronology of western North Pacific and North Indian Ocean tropical cyclones for 1993.

Table 3-3 WESTERN NORTH PACIFIC TROPICAL CYCLONES

TYPHOONS

(1945 - 1959)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.3	0.1	0.3	0.4	0.7	1.0	2.9	3.1	3.3	2.4	2.0	0.9	16.4
CASES	5	1	4	6	10	15	29	46	49	36	30	14	245

(1960 - 1993)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.3	0.1	0.2	0.4	0.7	1.1	2.7	3.3	3.3	3.2	1.8	0.7	17.8
CASES	10	2	7	15	24	38	93	112	112	108	61	23	605

TROPICAL STORMS AND TYPHOONS

(1945 - 1959)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.4	0.1	0.5	0.5	0.8	1.6	2.9	4.0	4.2	3.3	2.7	1.2	22.2
CASES	6	2	7	8	11	22	44	60	64	49	41	18	332

(1960 - 1993)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.6	0.3	0.5	0.6	1.1	1.9	4.2	5.5	5.0	4.2	2.8	1.2	27.7
CASES	19	9	16	22	37	63	142	186	169	144	94	41	942

NUMBER OF CALENDAR WARNING DAYS 181
NUMBER OF CALENDAR WARNING DAYS WITH TWO TROPICAL CYCLONES 49
NUMBER OF CALENDAR WARNING DAYS WITH THREE TROPICAL CYCLONES 12
NUMBER OF CALENDAR WARNING DAYS WITH FOUR TROPICAL CYCLONES 3

Table 3-4 TROPICAL CYCLONE FORMATION ALERTS FOR THE WESTERN NORTH PACIFIC OCEAN 1976-1993

YEAR	INITIAL TCFAS	TROPICAL CYCLONES WITH TCFAS	TOTAL TROPICAL CYCLONES	FALSE ALARM RATE*	PROBABILITY OF DETECTION
1976	34	25	25	26%	100%
1977	26	20	21	23%	95%
1978	32	27	32	16%	84%
1979	27	23	28	15%	82%
1980	37	28	28	24%	100%
1981	29	28	29	3%	96%
1982	36	26	28	28%	93%
1983	31	25	25	19%	100%
1984	37	30	30	19%	100%
1985	39	26	27	33%	96%
1986	38	27	27	29%	100%
1987	31	24	25	23%	96%
1988	33	26	27	21%	96%
1989	51	32	35	37%	91%
1990	33	30	31	9%	97%
1991	37	29	31	22%	94%
1992	36	32	32	20%	100%
1993	50	35	38	30%	92%
(1976-1993)					
MEAN:	35.4	27.4	28.8	23%	95%
TOTALS:	637	493	519		

* The false alarm rate is the difference between the number of initial TCFA's and the number of Tropical Cyclones with TCFA's divided by the number of inital TCFA's and is expressed as a percentage.

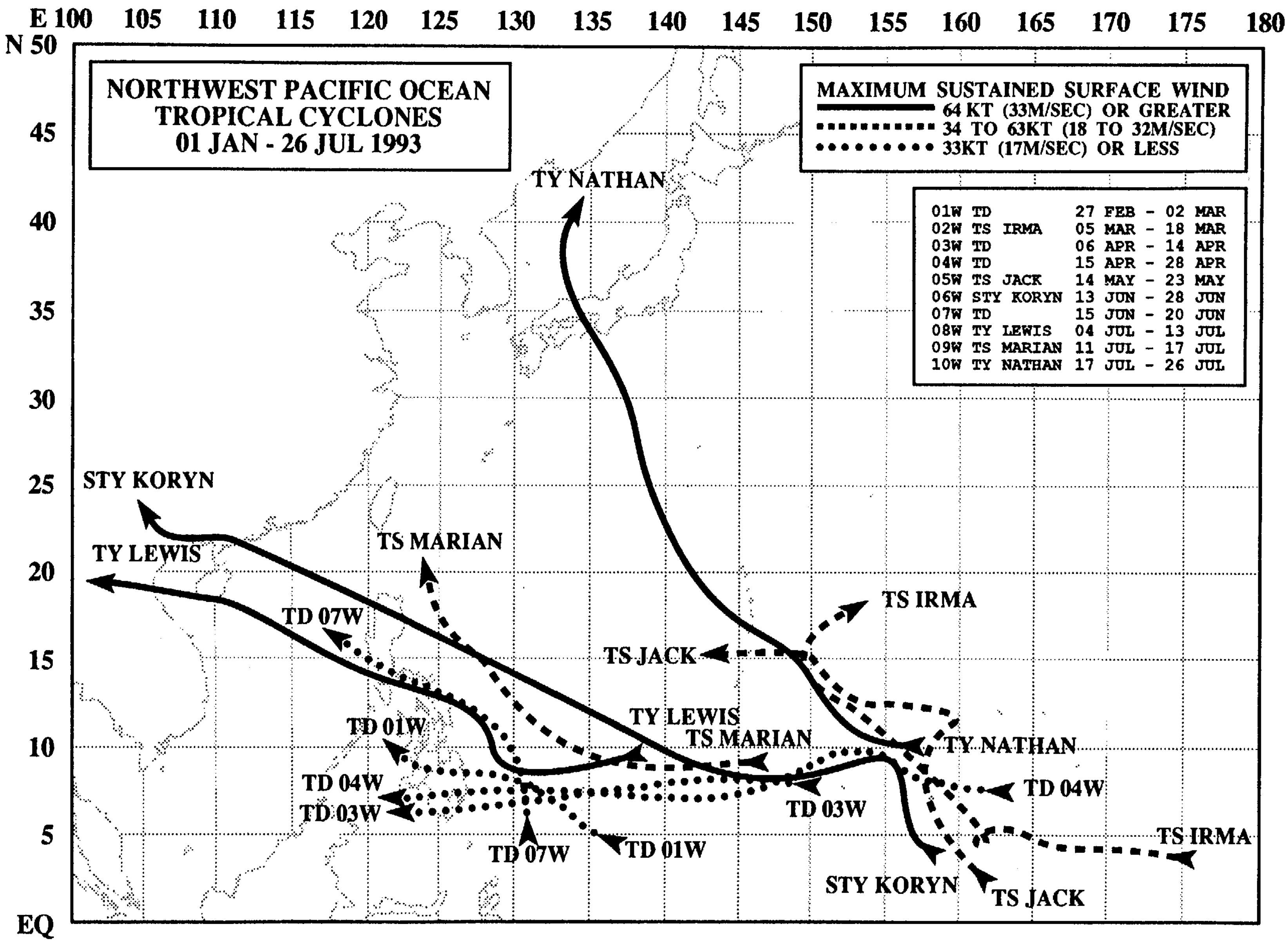


Figure 3-10 Composite best tracks for the North West Pacific Ocean tropical cyclones for the period 1 January to 26 July 1993.

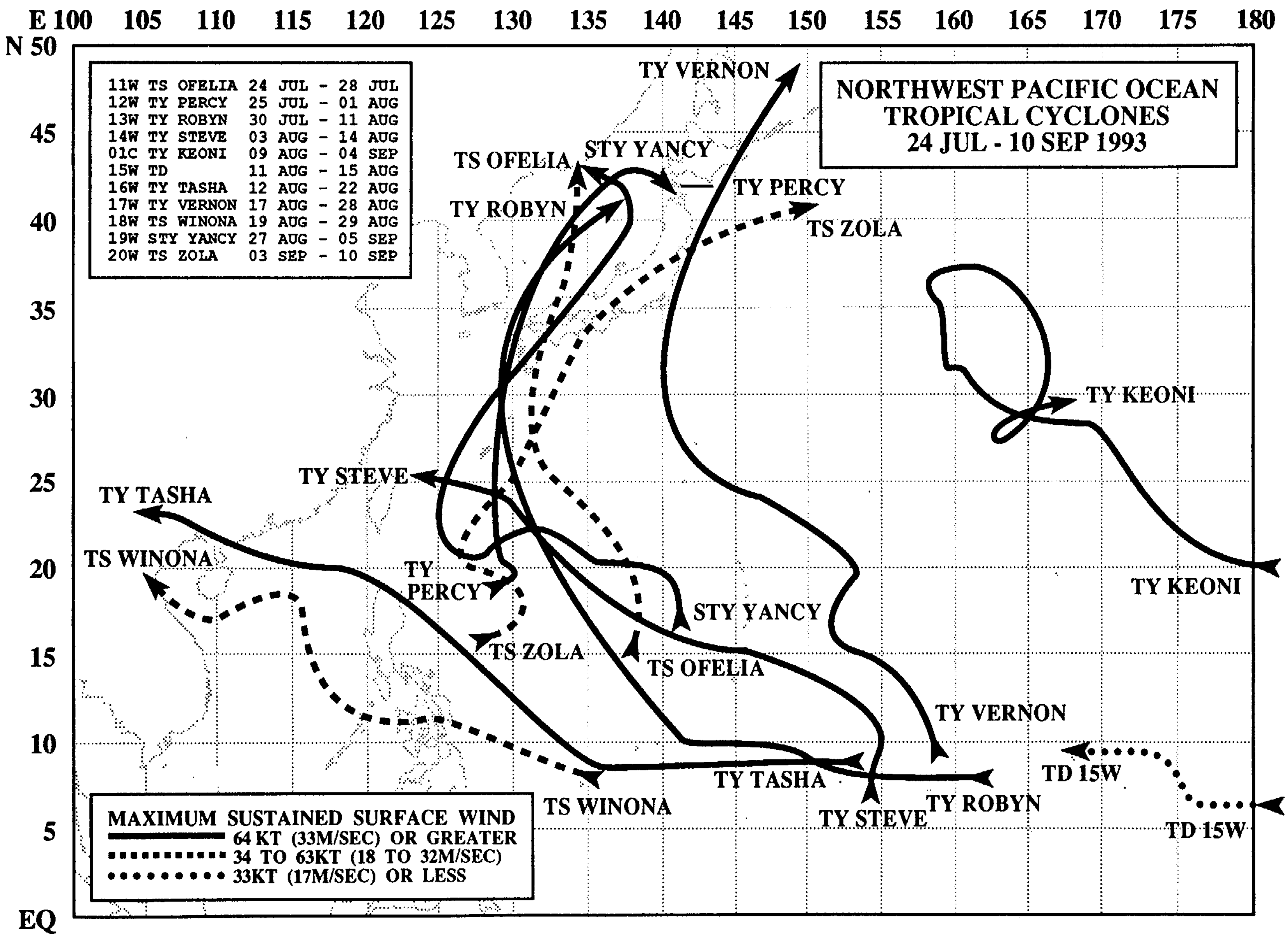


Figure 3-11 Composite best tracks for the North West Pacific Ocean tropical cyclones for the period 24 July to 10 September 1993.

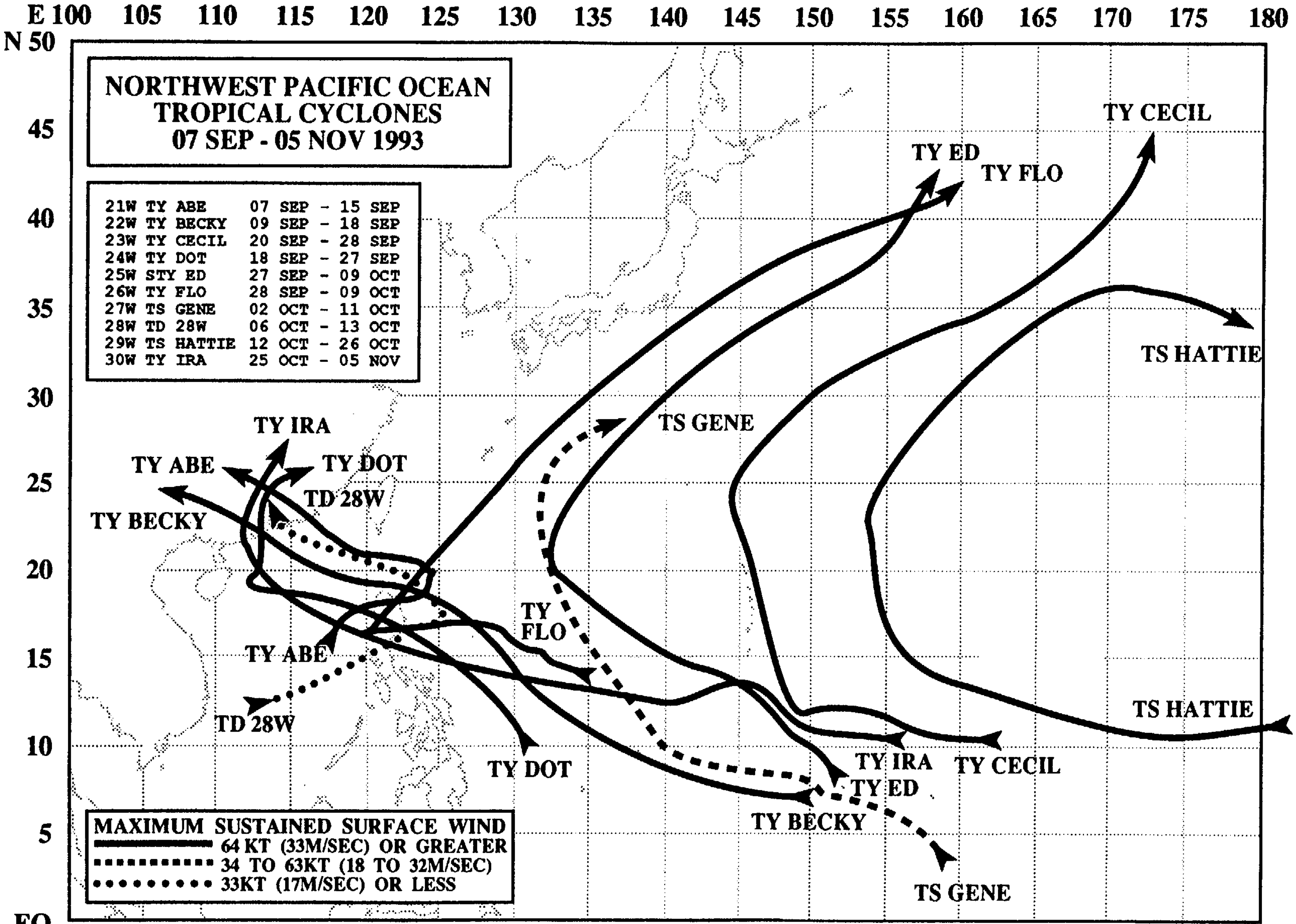


Figure 3-12 Composite best tracks for the North West Pacific Ocean tropical cyclones for the period 7 September to 5 November 1993.

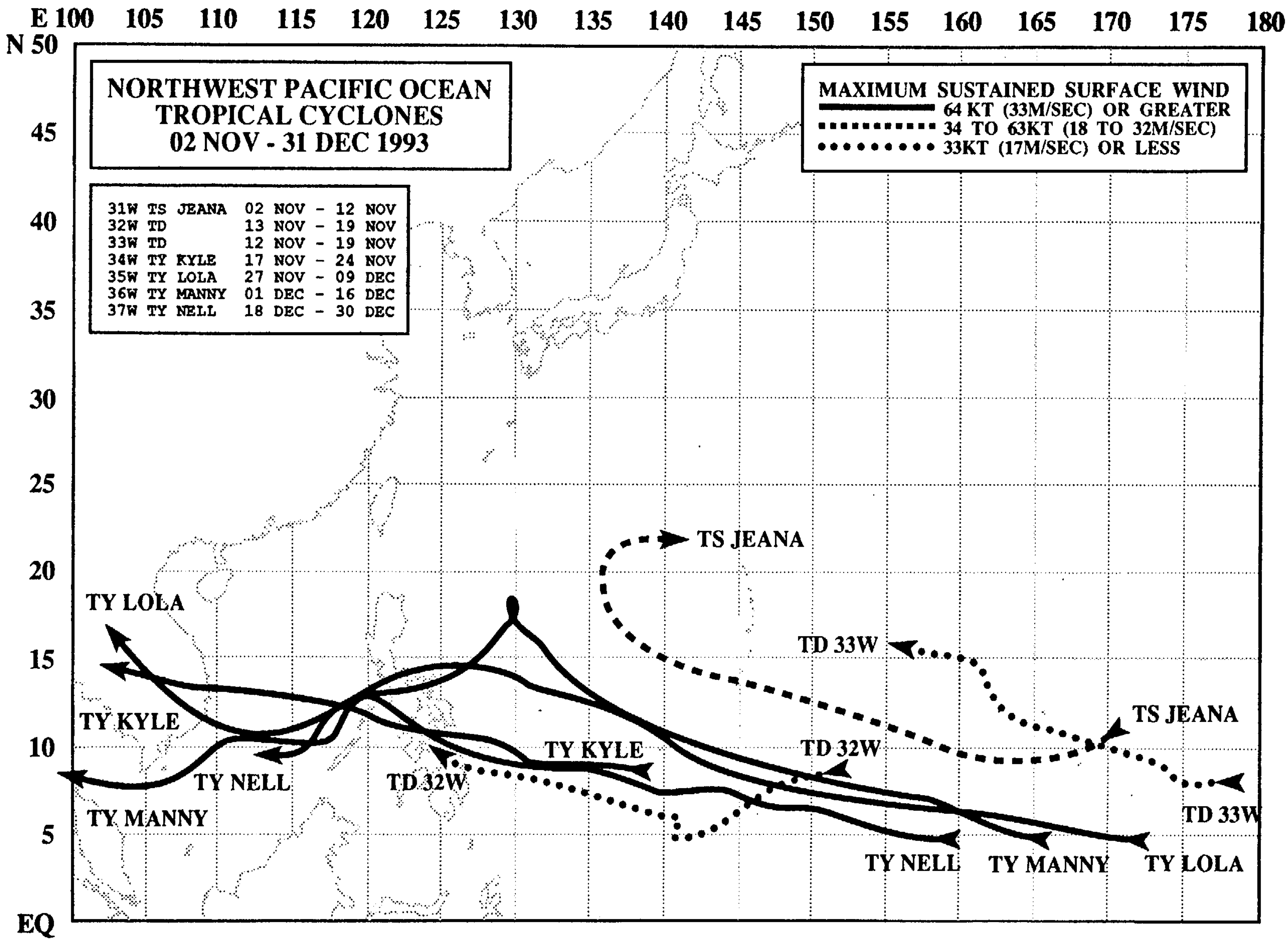
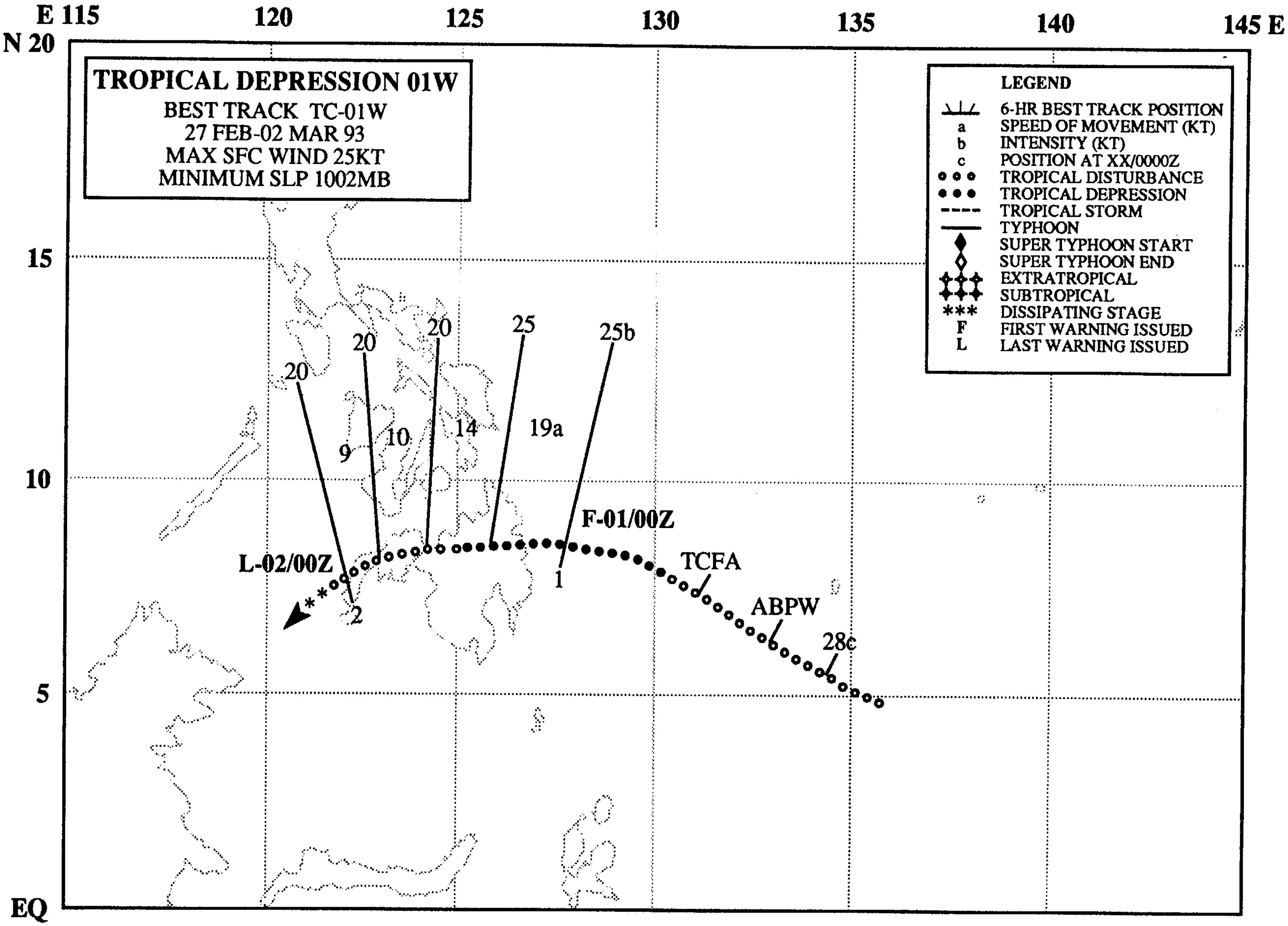


Figure 3-13 Composite best tracks for the North West Pacific Ocean tropical cyclones for the period 2 November to 31 December 1993.


TROPICAL DEPRESSION 01W
BEST TRACK TC-01W
27 FEB-02 MAR 93
MAX SFC WIND 25KT
MINIMUM SLP 1002MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 115
120
125
130
135
140
145 E
N 20
15
10
5
EQ
F-01/00Z
L-02/00Z
TCFA
ABPW
28c
25b
19a
1
2
20
20
20
25
9
10
14

TROPICAL DEPRESSION 01W

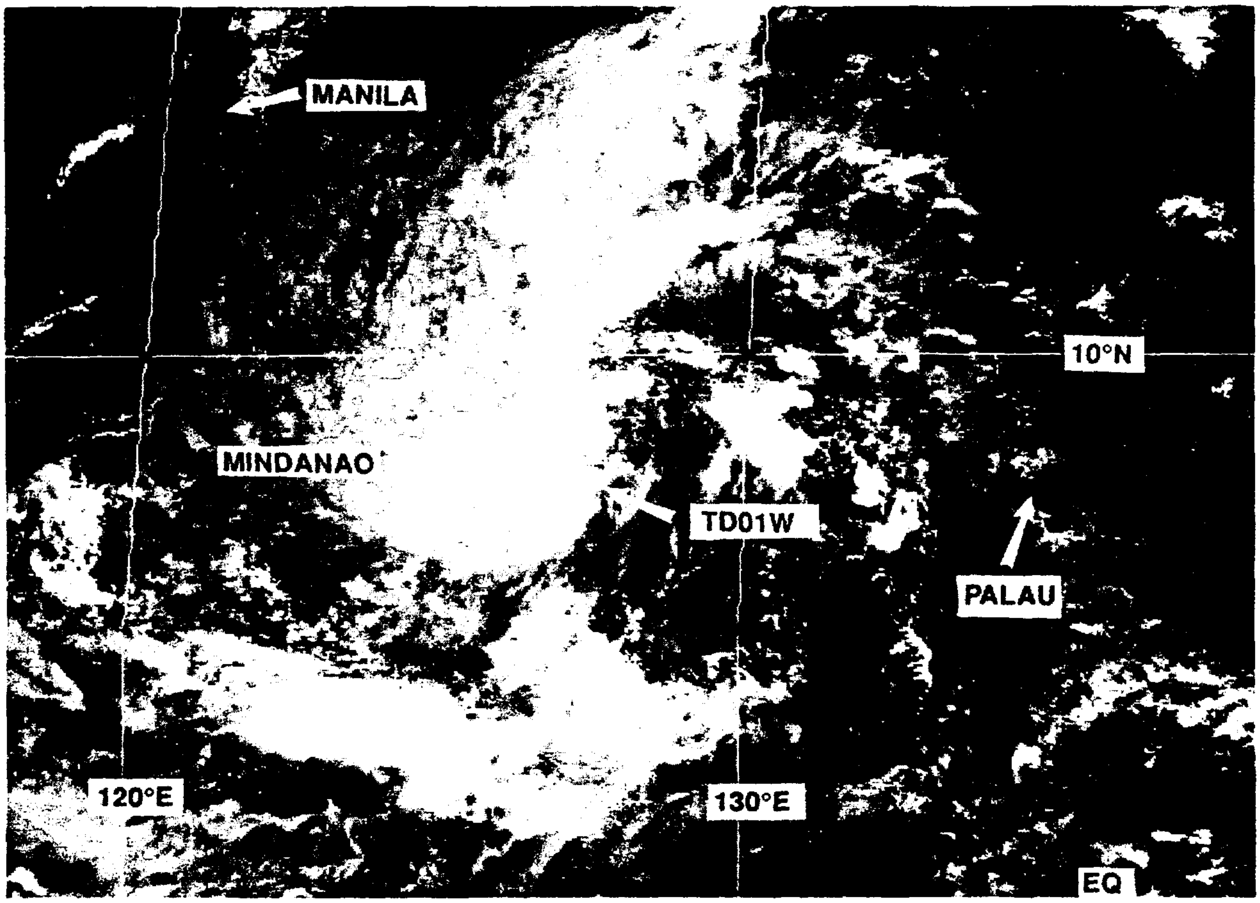


Figure 3-01-1 TD 01W approaches the island of Mindanao (010030Z March visual GMS imagery).

I. HIGHLIGHTS

The first tropical cyclone to occur in the western North Pacific Ocean in 1993, and the first of two significant tropical cyclones to occur in March, Tropical Depression 01W was a short-lived system that required only five warnings. It began as a tropical disturbance in the near-equatorial trough southeast of Palau in the western Caroline Islands and ended by dissipating over the mountainous terrain of Mindanao Island in the Philippines.

II. CHRONOLOGY OF EVENTS

February

280600Z - Tropical Depression 01W was first mentioned on the Significant Tropical Weather Advisory based on convection flaring up over a preexisting low-level cyclonic circulation.

281230Z - Persistent convection near the circulation center led to the issuance of a Tropical Cyclone Formation Alert.

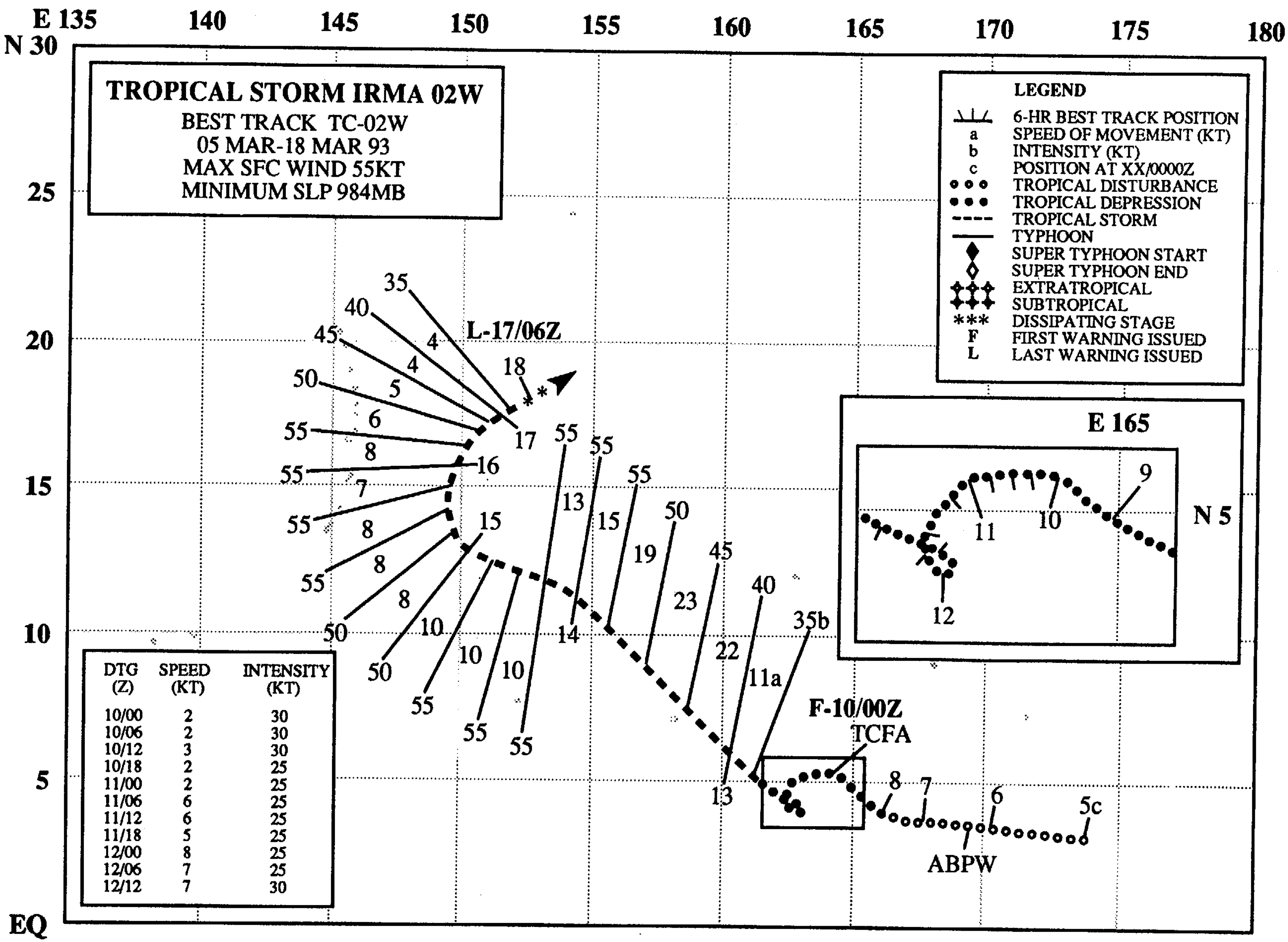
March

010000Z - The initial warning was released based on the first visual satellite image of the day, which showed improved convective organization and a satellite intensity estimate of 25 kt (13 m/sec) (Figure 3-01-1).

020000Z - The final warning was issued following rapid weakening over the rugged island of Mindanao in the southern Philippine Islands.

III. IMPACT

Heavy rains near the Mayon volcano, 180 nm (335 km) southeast of Manila, caused mudslides. No injuries or deaths were reported.



DTG (Z)	SPEED (KT)	INTENSITY (KT)
10/00	2	30
10/06	2	30
10/12	3	30
10/18	2	25
11/00	2	25
11/06	6	25
11/12	6	25
11/18	5	25
12/00	8	25
12/06	7	25
12/12	7	30

TROPICAL STORM IRMA (02W)

I. HIGHLIGHTS

The first tropical cyclone to reach tropical storm intensity in the western North Pacific Ocean during 1993, Irma formed from a strong equatorial westerly wind burst which also generated a twin tropical cyclone in the Southern Hemisphere - Tropical Cyclone Roger (22P). After moving toward the southern Mariana Islands for 10 days, Irma briefly threatened Guam, moved northeastward and dissipated.

II. CHRONOLOGY OF EVENTS

March

060600Z - The disturbance was first mentioned on the Significant Tropical Weather Advisory south of the Marshall Islands based upon synoptic reports which indicated a weak low-level circulation near the eastern end of extensive cloudiness associated with the west wind burst.

092330Z - The consolidation of convection near the low-level circulation center led to issuance of a Tropical Cyclone Formation Alert (TCFA). Post analysis of satellite and synoptic data indicate Irma attained tropical depression status two days earlier at 080000Z.

100000Z - The first warning on Tropical Depression 02W closely followed the TCFA when a 30 kt (15 m/sec) surface wind report was received from Kosrae (WMO 91356).

121800Z - As the twin systems moved farther apart, Tropical Depression 02W was upgraded to Tropical Storm Irma based on a satellite intensity estimate of 35 kt (18 m/sec).

170600Z - The final warning was issued as Irma dissipated in a vertically sheared and stable trade-wind environment.

III. IMPACT

None. However, an accurate recurvature forecast allowed aircraft positioned at Andersen AFB, Guam for Team Spirit 93 to remain in-place.

IV. DISCUSSION

On 08 March 1993, a band of low-level westerlies stretched along the equator from about 120°E to the international date line. These westerlies were confined to very low latitudes by two near-equatorial troughs, one at about 5°N, the other at about 5°S.

At the eastern terminus of the equatorial westerly flow, two weak cyclonic circulations, symmetrical with respect to the equator, had formed (Figure 3-02-1). A ship report of 30 kt (15 m/sec) near the equator at 155°E indicated that an equatorial westerly wind burst had commenced. Three days later, on 10 March, the deep convective cloud -- which had been clustered along the equator (Figure 3-02-2) — began to consolidate into tropical cyclone twins (Figure 3-02-3). (Note: the term, "tropical cyclone twins", implies a symmetry with respect to the equator.) By 13 March, the twin tropical cyclones — Irma in the Northern Hemisphere, and Tropical Cyclone Roger (22P) in the Southern Hemisphere — had become mature tropical cyclones heading westward and poleward into their respective hemisphere. As with other twin-cyclone events, by the time the tropical cyclones had matured, the cloudiness along the equator had collapsed (Lander, 1990). Roger (22P) and Irma continued an unbroken sequence of the occurrence of tropical cyclone twins once every year since 1991: Walt and Lisa, May 1991; Axel and Betsy, January 1992; and, Roger (22P) and Irma, March 1993.

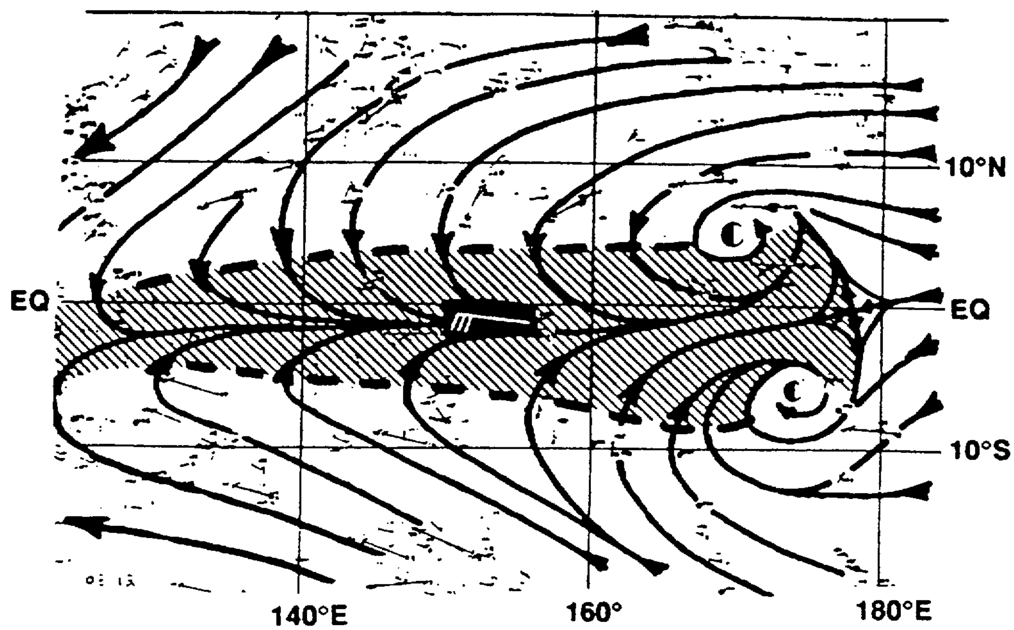


Figure 3-02-1 Streamline analysis of the low-level wind field at 081200Z March. Shaded region shows area of westerly wind flow. The cyclonic circulation centers later become the tropical cyclone twins — Irma and Roger (22P).

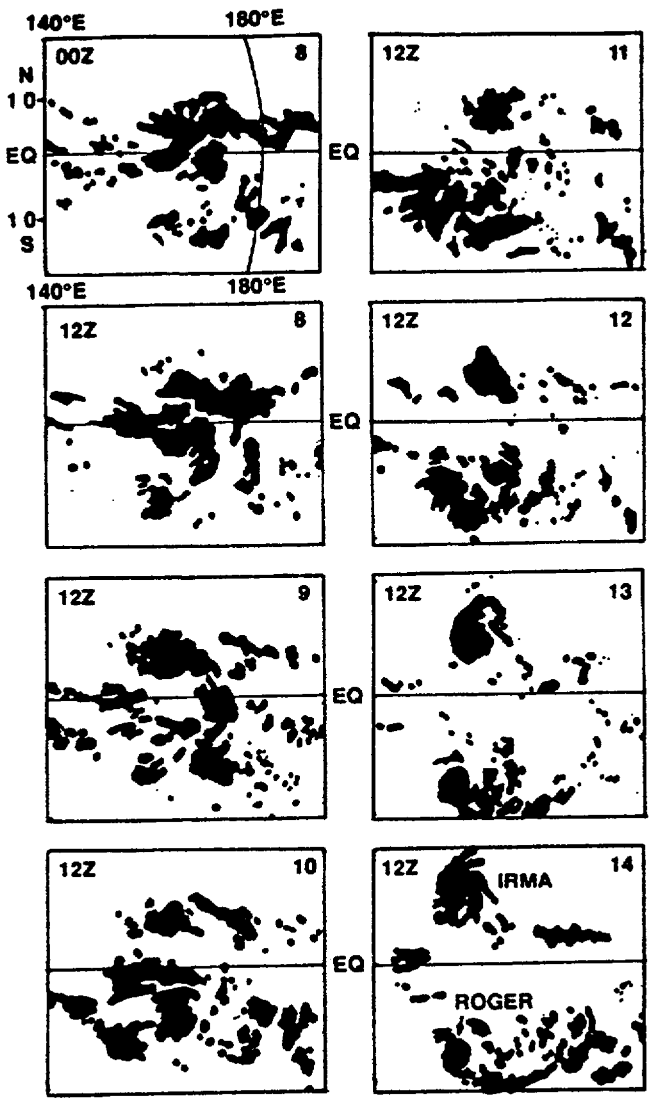


Figure 3-02-2 Cloud silhouettes for the period 8 to 14 March show the development of Irma and Roger (22P).

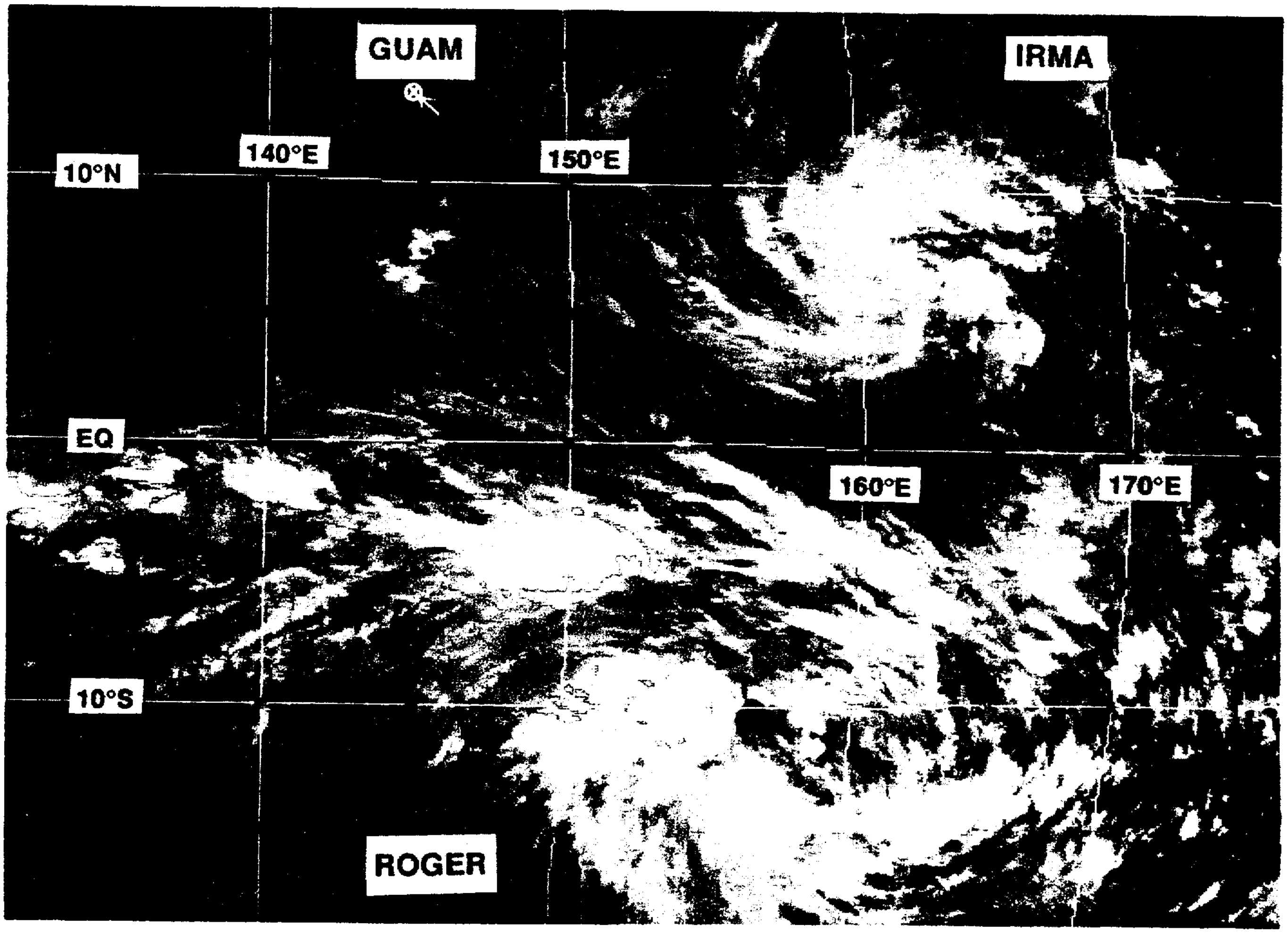
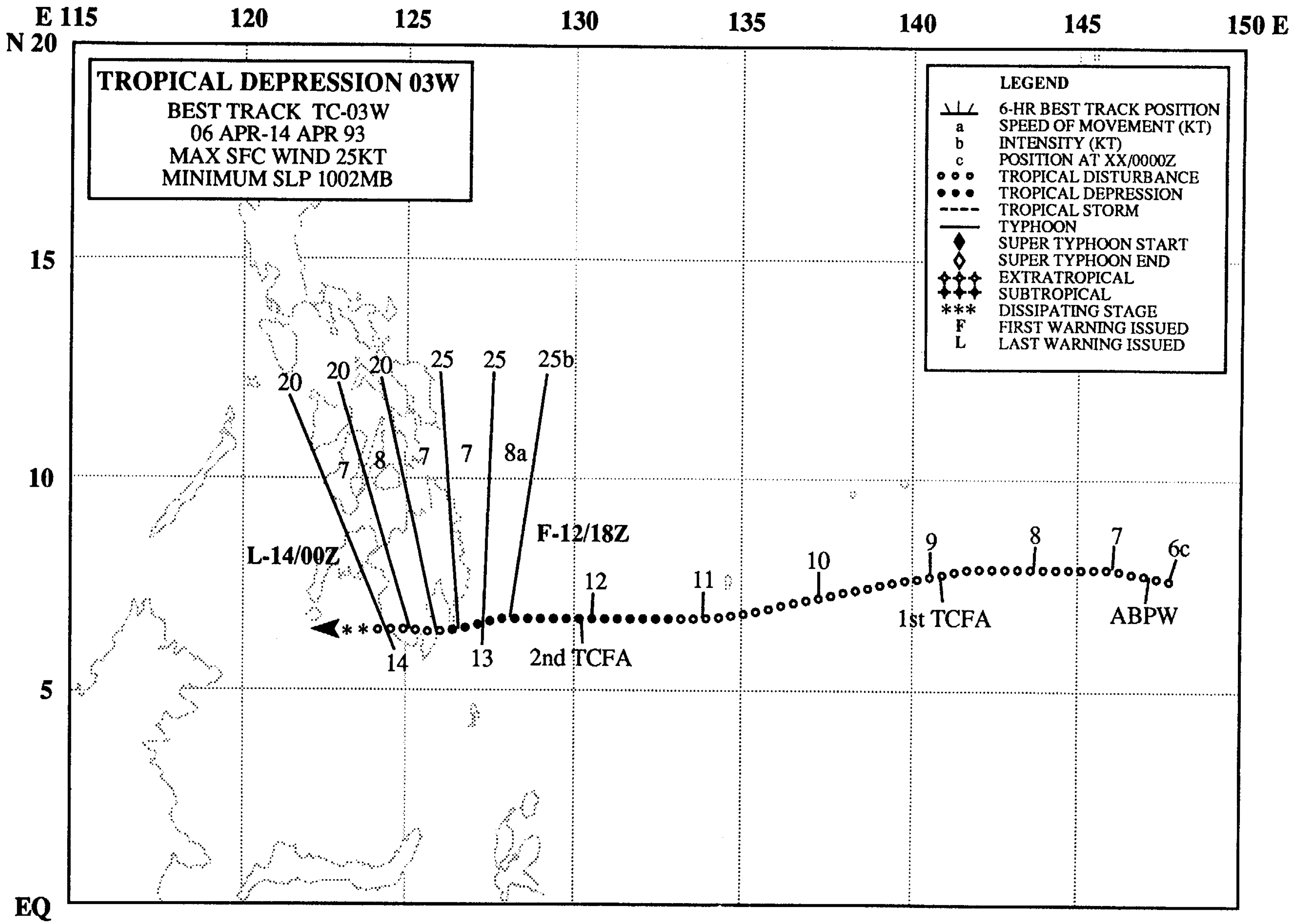


Figure 3-02-3 Tropical cyclone twins Irma and Roger (22P) are shown (120030Z March infrared GMS imagery).



TROPICAL DEPRESSION 03W
BEST TRACK TC-03W
06 APR-14 APR 93
MAX SFC WIND 25KT
MINIMUM SLP 1002MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 115
120
125
130
135
140
145
150 E
N 20
15
10
5
EQ
L-14/00Z
F-12/18Z
1st TCFA
2nd TCFA
ABPW

TROPICAL DEPRESSION 03W

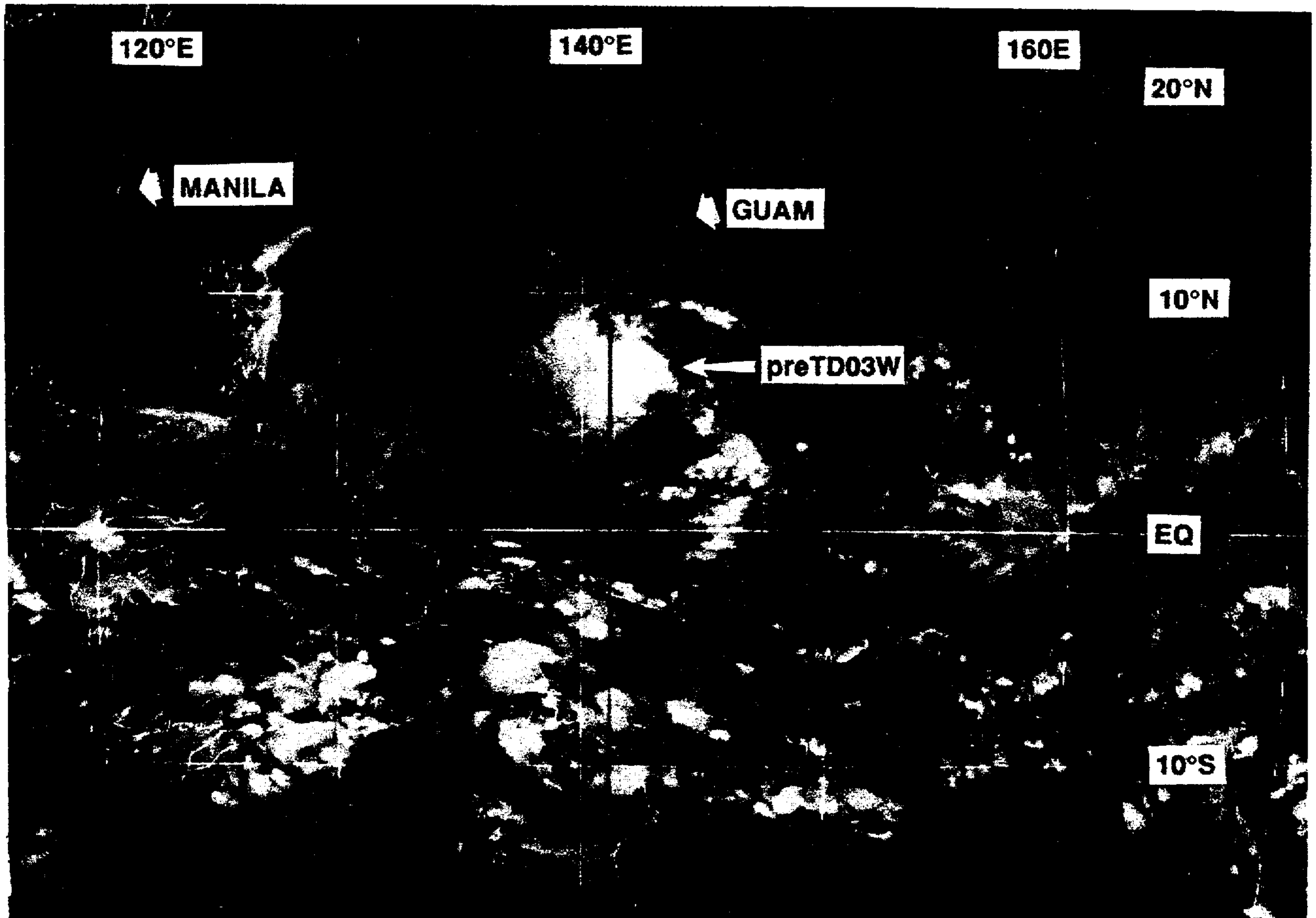


Figure 3-03-1 Convection associated with the tropical disturbance — later TD03W — flares up in early morning hours which is the normal time for the maximum cloudiness (081730Z April infrared GMS imagery).

I. HIGHLIGHTS

The first of two significant tropical cyclones to form in the near-equatorial trough during April, Tropical Depression 03W moved steadily westward, weakened over the island of Mindanao in the southern Philippines, and dissipated.

II. CHRONOLOGY OF EVENTS

April

060600Z - The disturbance was first mentioned in the Significant Tropical Weather Advisory as an area of persistent convection near Chuuk in the eastern Caroline Islands.

082330Z - The consolidation of convection around the low-level circulation center led to the issuance of a Tropical Cyclone Formation Alert (TCFA) (Figure 3-03-1¡).

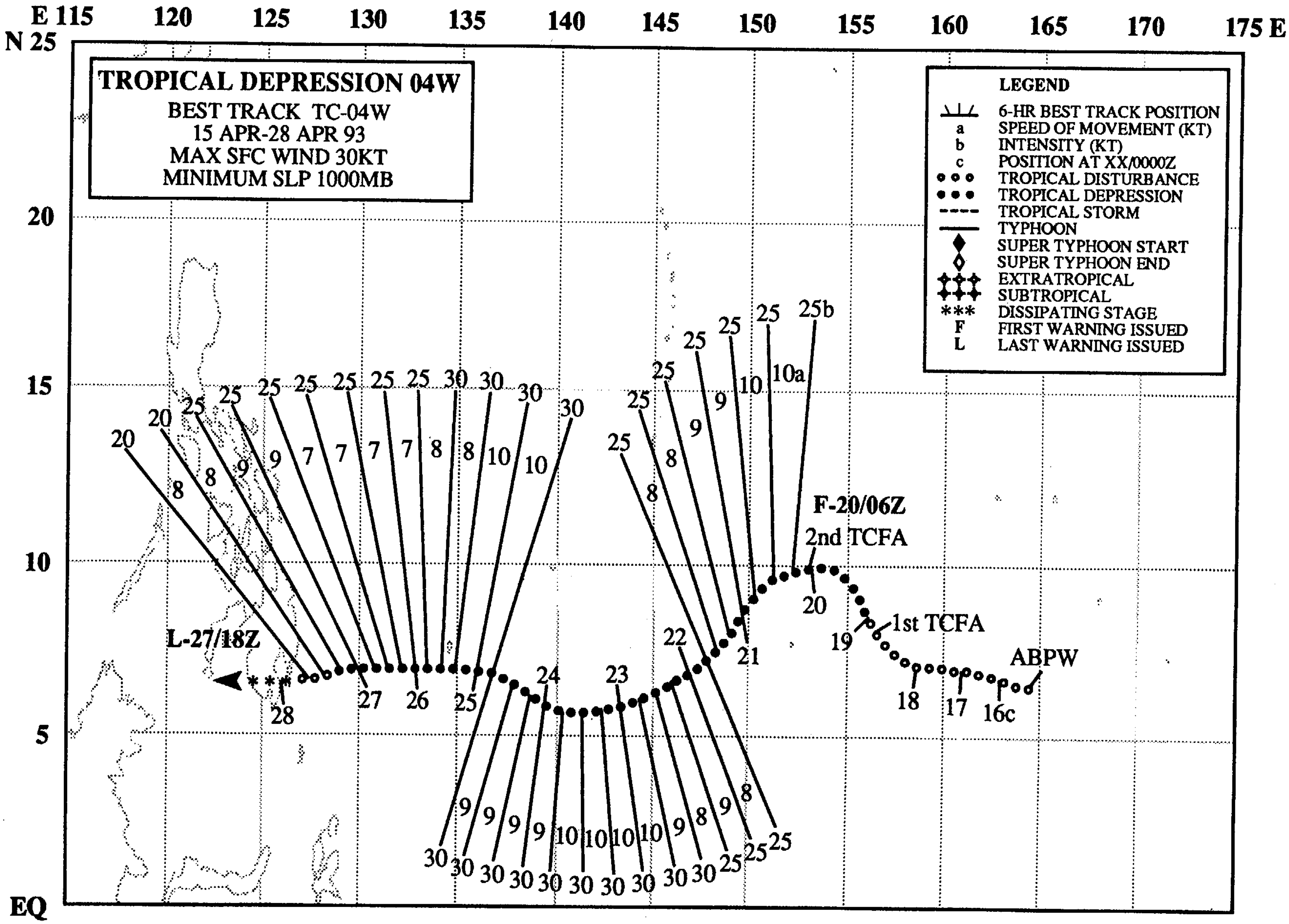
092330Z - The TCFA was canceled due to a steady decrease in convection during the previous 24 hours.

120300Z - A second TCFA was issued based upon increasing convection over the preexisting low-level circulation center.

121800Z - Initial warning was issued on Tropical Depression 03W based on ship synoptic wind reports of 25 kt (13 m/sec).
140000Z - Final warning was issued as Tropical Depression 03W weakened over the rugged island of Mindanao.

III. IMPACT

None.


TROPICAL DEPRESSION 04W
BEST TRACK TC-04W
15 APR-28 APR 93
MAX SFC WIND 30KT
MINIMUM SLP 1000MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 115
120
125
130
135
140
145
150
155
160
165
170
175 E
N 25
20
15
10
5
EQ
F-20/06Z
2nd TCFA
1st TCFA
ABPW
L-27/18Z
16c
17
18
19
20
21
22
23
24
25
26
27
28
25b
10a

TROPICAL DEPRESSION 04W

I. HIGHLIGHTS

A day after Tropical Depression 03W dissipated over Mindanao, Tropical Depression 04W formed in the near-equatorial trough in the Marshall Islands during a period of enhanced cloudiness associated with a westerly wind burst along the equator. Like its predecessor, Tropical Depression 03W, this tropical cyclone tracked westward through the Caroline Islands and over southern Mindanao, where it dissipated (Figure 3-04-1).

II. CHRONOLOGY OF EVENTS

April

150600Z - The disturbance was first mentioned in the Significant Tropical Weather Advisory as a broad area of persistent convection within the near-equatorial trough.

181900Z - A significant increase in central convection led to the issuance of a Tropical Cyclone Formation Alert (TCFA).

191900Z - The TCFA was canceled due to a steady decrease in the amount of convection during the previous 24 hours.

200200Z - A second TCFA was issued based upon increasing convection over the low-level circulation center and a 20 kt (10 m/sec) ship report in the vicinity.

200600Z - The first warning was released based upon the persistent of a central cloud feature and satellite intensity estimate of 30 kt (15 m/sec).

271800Z - The final warning was issued as the tropical cyclone dissipated over the island of Mindanao in the Philippines.

III. IMPACT

None.

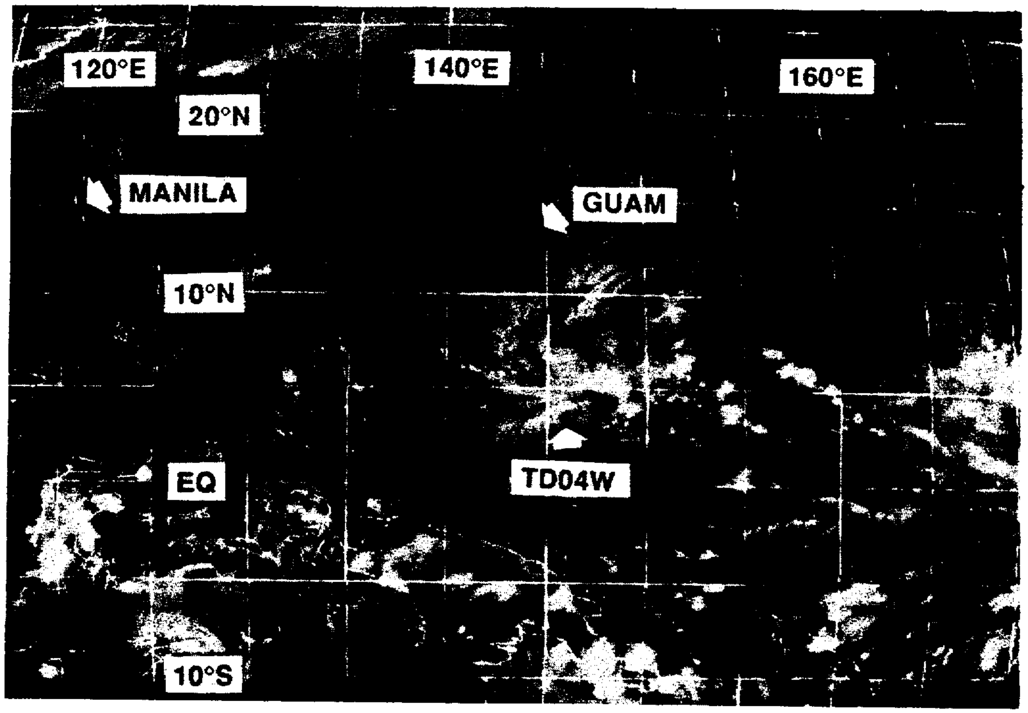
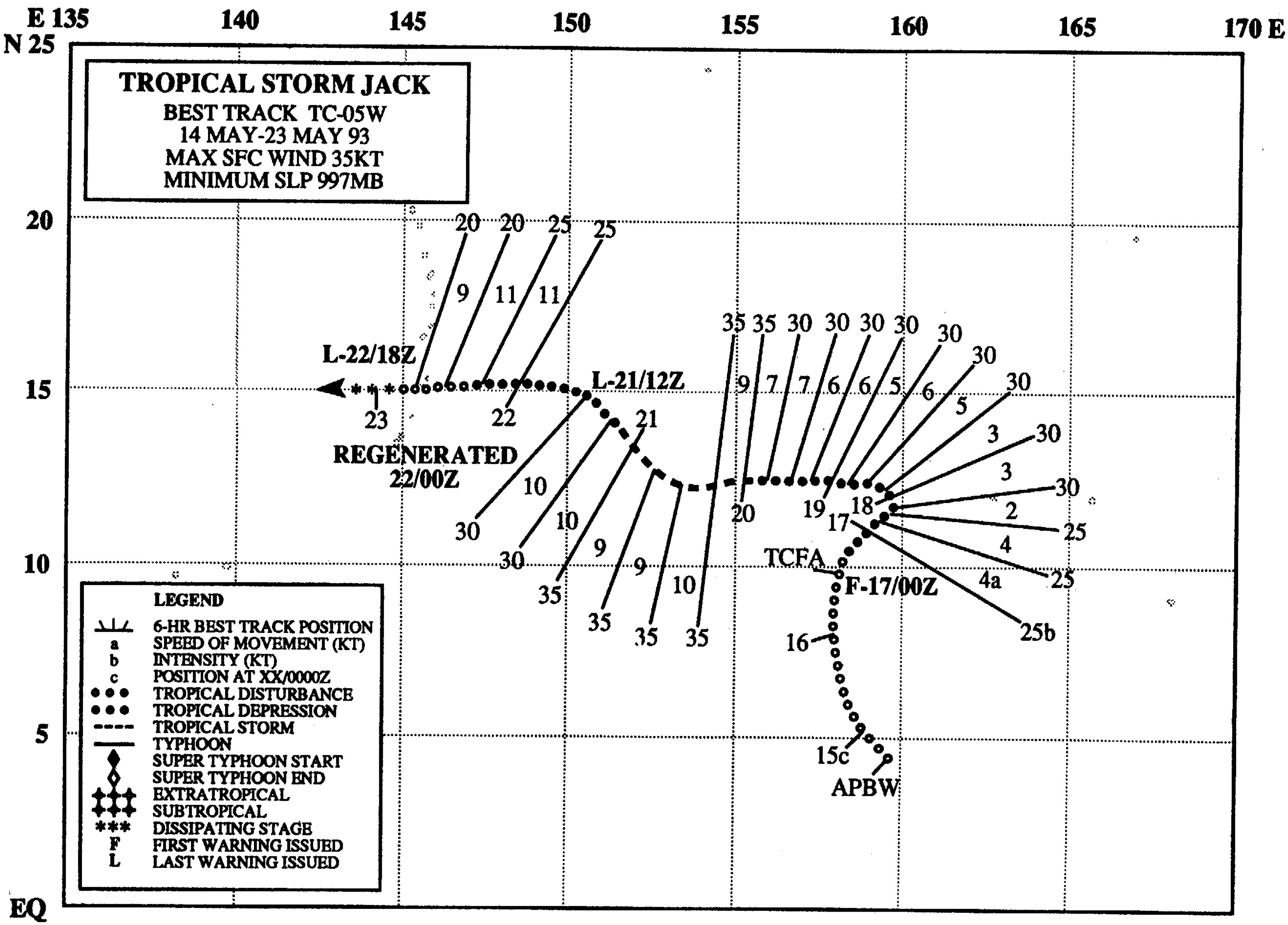


Figure 3-04-1 TD 04W passes to the south of Guam (221130Z April infrared GMS imagery).


TROPICAL STORM JACK
BEST TRACK TC-05W
14 MAY-23 MAY 93
MAX SFC WIND 35KT
MINIMUM SLP 997MB
E 135
140
145
150
155
160
165
170 E
N 25
20
15
10
5
EQ
L-22/18Z
L-21/12Z
REGENERATED
22/00Z
TCFA
F-17/00Z
APBW
15c
4a
25b
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TROPICAL STORM JACK (05W)

I. HIGHLIGHTS

The only significant tropical cyclone to occur during May, Tropical Storm Jack developed in association with an equatorial westerly wind burst (Luther et al., 1983), that involved Tropical Cyclone 27P (Adel) in the Solomon Islands in the Southern Hemisphere. As the maximum cloudiness associated with the westerly burst decreased, Jack moved steadily northward until 18 May when it turned to the west. Four days later, the tropical cyclone dissipated west of Saipan.

II. CHRONOLOGY OF EVENTS

May

140600Z - The tropical disturbance was first mentioned in the Significant Tropical Weather Advisory as an area of persistent convection to the south of Pohnpei in the eastern Caroline Islands.

161300Z - Tropical Cyclone Formation Alert was issued based on the appearance of a ragged central dense overcast.

170000Z - JTWC released the first warning on Tropical Depression 05W after analysis of the first daylight visual satellite imagery and receiving an intensity estimate of 25 kt (13 m/sec).

180600Z - Based on an satellite intensity estimate of 35 kt (18 m/sec), Jack was upgraded to a tropical storm. (Post analysis indicates Jack most probably became a tropical storm 42 hours later at 200000Z.)

211200Z - The loss of central convection led JTWC to issue a last warning on the circulation.

220000Z - Reintensification of Jack, as indicated by the appearance of persistent central convection, prompted JTWC to resume warnings (Figure 3-05-1).

221800Z - JTWC issued its final warning on Jack as the circulation dissipated just west of Saipan due to increased upper-level wind shear.

III. IMPACT

None.

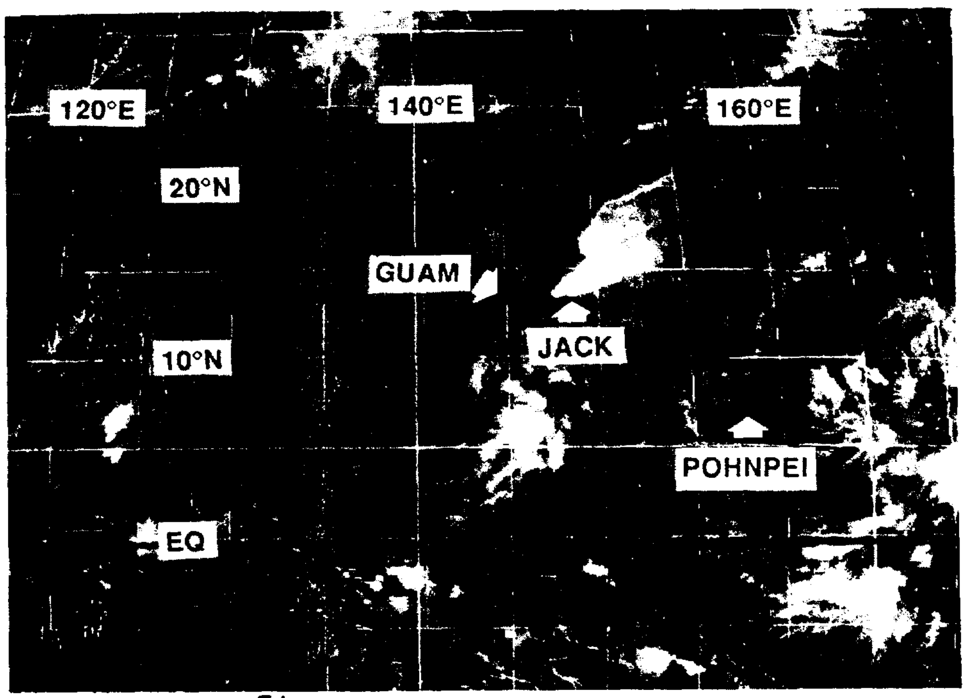
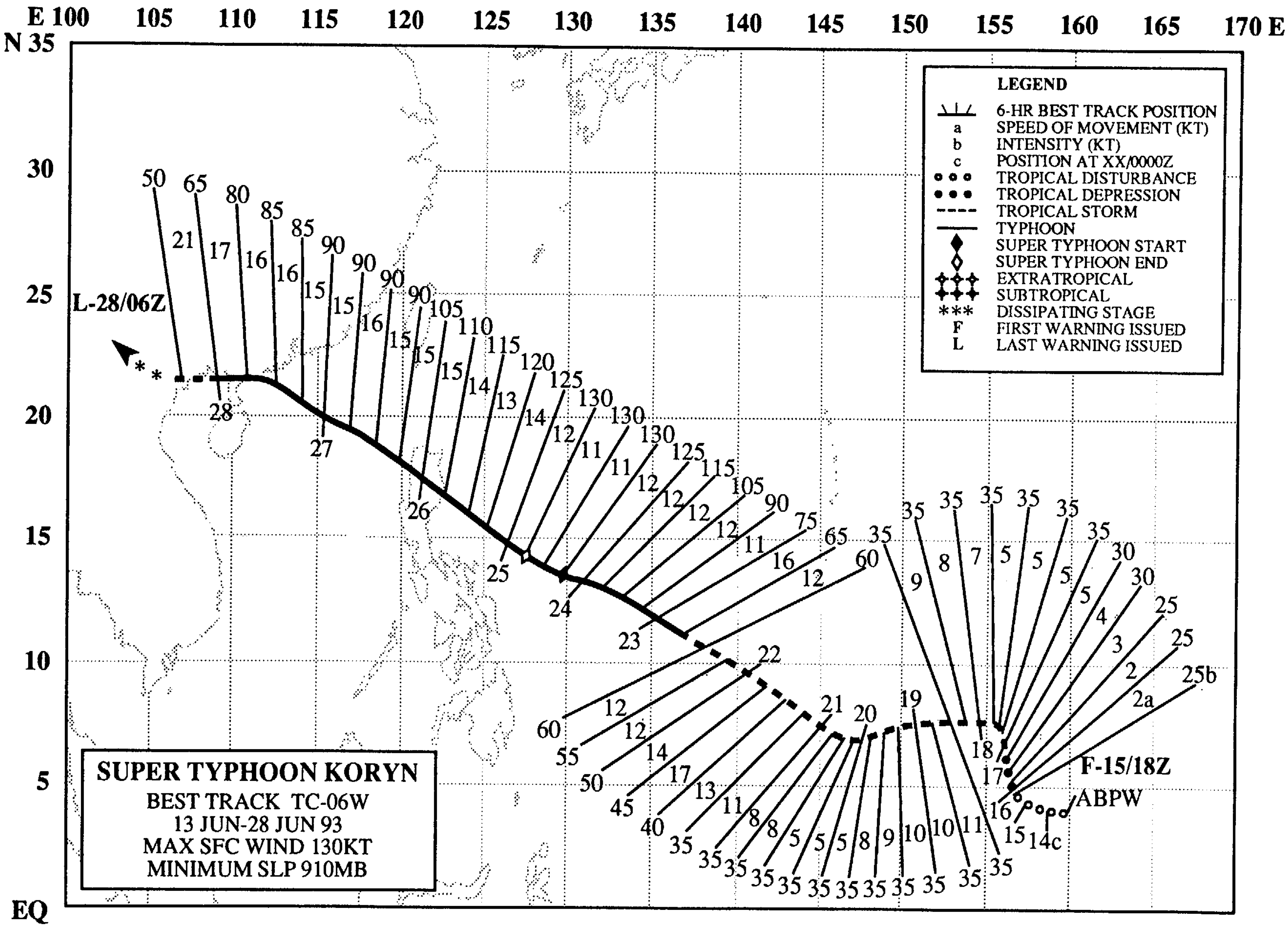


Figure 3-05-1 Jack's convection reappears just to the east of Guam (220132Z May infrared GMS imagery).


E 100
105
110
115
120
125
130
135
140
145
150
155
160
165
170 E
N 35
30
25
20
15
10
5
EQ
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-28/06Z
F-15/18Z
ABPW
SUPER TYPHOON KORYN
BEST TRACK TC-06W
13 JUN-28 JUN 93
MAX SFC WIND 130KT
MINIMUM SLP 910MB

SUPER TYPHOON KORYN (06W)

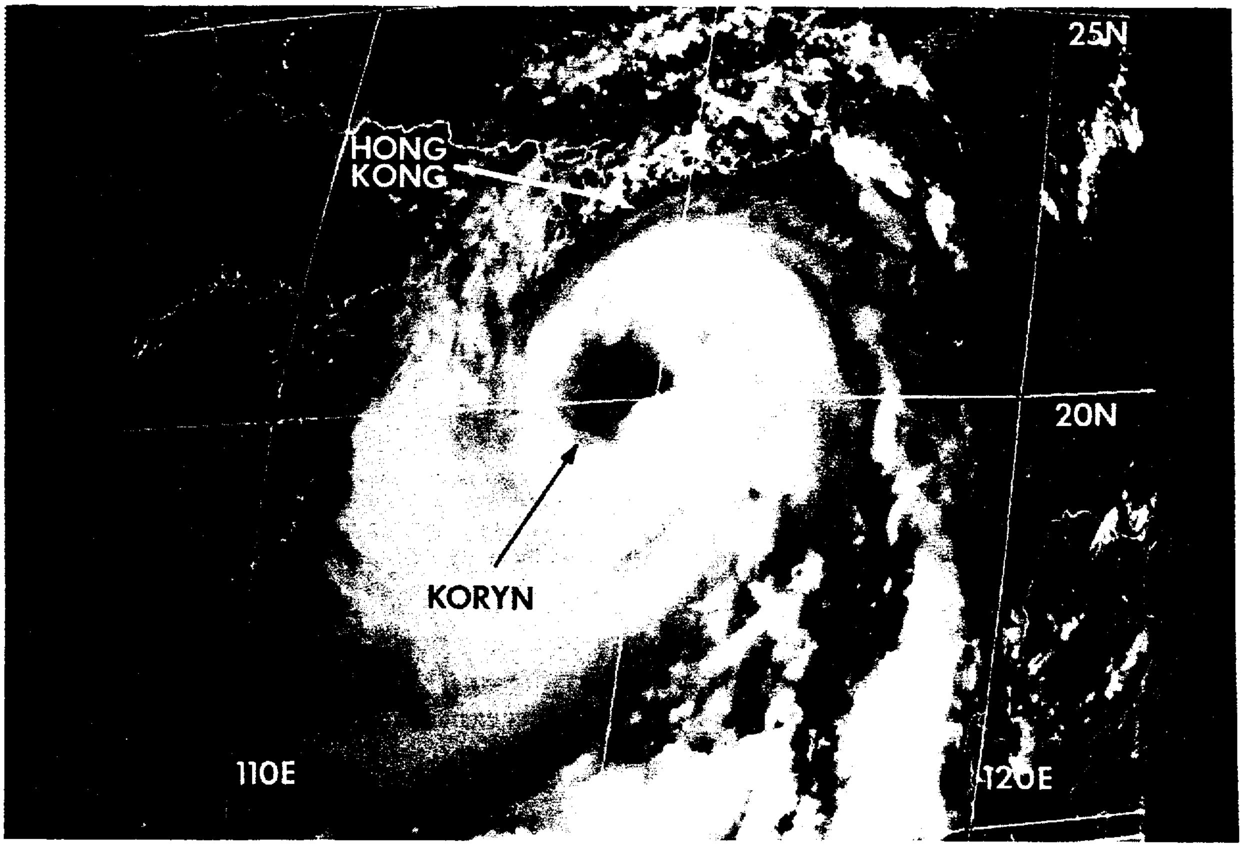


Figure 3-06-1 Koryn exhibits a large, ragged, cloud-free eye as it passes south of Hong Kong (262333Z June visual NOAA imagery).

I. HIGHLIGHTS

The first typhoon of the 1993 in western North Pacific, Koryn intensified slowly, taking over a week to attain minimal typhoon force winds. However, in 24 hours after its winds reached 65 kt (33 m/sec), the tropical cyclone rapidly doubled its intensity to become a super typhoon. After striking northern Luzon, Koryn entered the South China Sea and passed 90 nm (165 km) to the southeast of Hong Kong. Hong Kong experienced wind gusts to 92 kt (47 m/sec) and torrential rains (Figure 3-06-1).

II. CHRONOLOGY OF EVENTS

June

131800Z - The disturbance was first mentioned in the Significant Tropical Weather Advisory as an area of persistent convection located in the near equatorial trough in the eastern Caroline Islands.

151800Z - The first warning was issued based on a 25 kt (13 m/sec) northwesterly wind at Nukuoro Atoll (WMO 91425) and a satellite intensity estimate of 25 kt (13 m/sec).

170000Z - Based on a satellite intensity estimate of 35 kt (18 m/sec), Koryn was upgraded to a tropical storm.

230000Z - The appearance of a small 10 nm (19 km) diameter eye and the resulting satellite intensity estimate of 65 kt (33 m/sec) prompted an upgrade of Koryn to a typhoon.

240600Z - Based on a satellite Dvorak intensity estimate of 127 kt (65 m/sec), Koryn was upgraded to a super typhoon.

280600Z - The final warning was issued on Koryn as it rapidly dissipated over the mountains of northern Vietnam.

III. IMPACT

The passage of Koryn over Ulithi (WMO 91203) gave the island 5.53 in (140 mm) of rain and 60 kt (31 m/sec) winds. While there were no deaths or injuries reported, there was extensive damage to crops and vegetation as well as some roof damage to structures. In the Philippines on the island of Luzon, floods and landslides caused by Koryn's torrential rains left at least 28 people dead. Damage to crops, infrastructure, homes, and livestock was estimated to be over (US)$14.5 million.

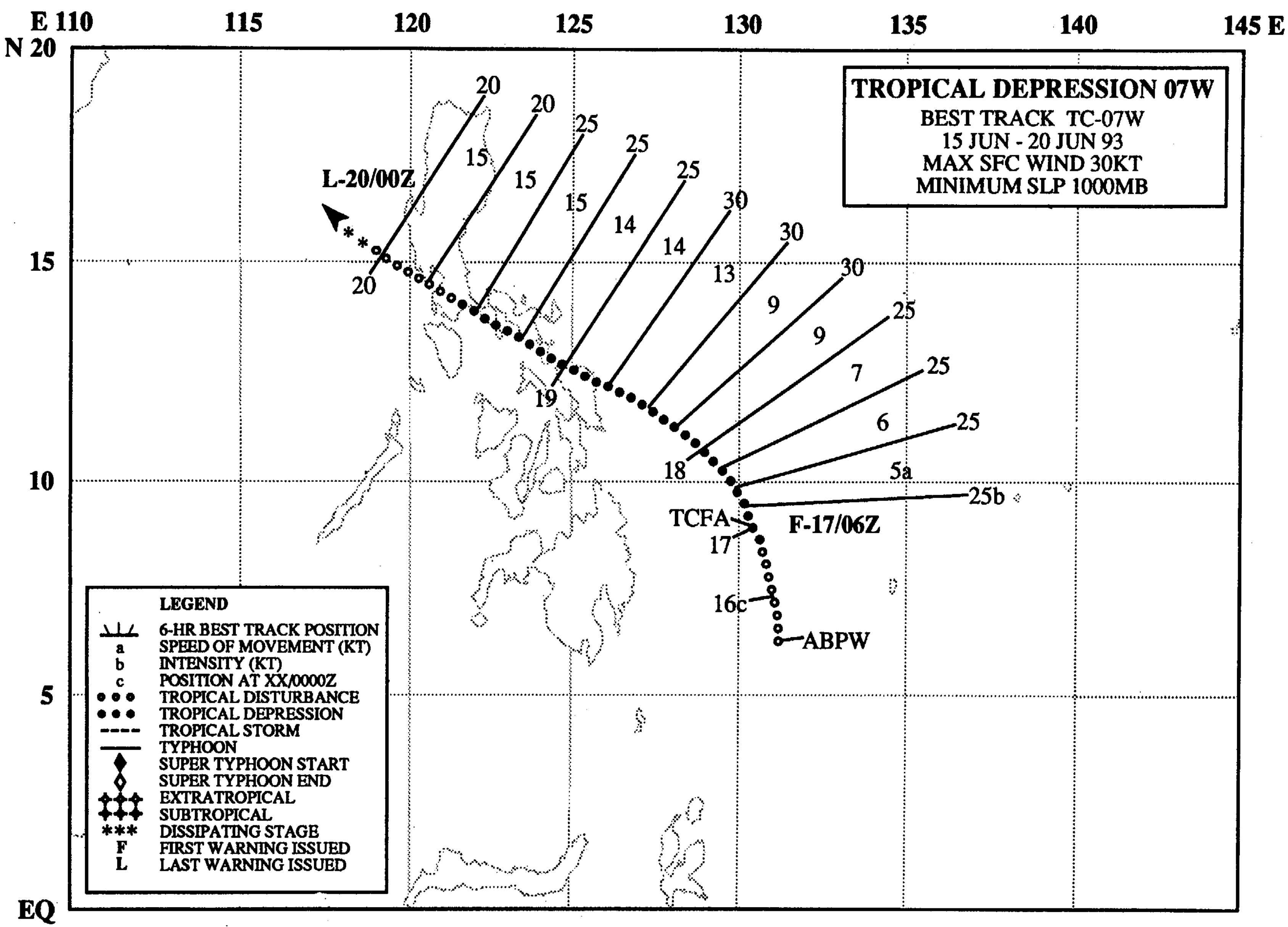
In Hong Kong, at least 183 people were injured, and a freighter, the 12,522-ton Lian Gang, sank 65 nm (120 km) southeast of Hong Kong with the loss of four of the crew. Koryn also lashed the coast of southern China's Guangdong Province, killing at least five people. No reports were received from Vietnam.

IV. DISCUSSION

The disturbance, that was to become Super Typhoon Koryn, first appeared at very low latitude (4°N) in the eastern Caroline Islands (near 160°E). From this birthplace, the disturbance moved northward, and then, upon attaining minimal tropical storm intensity, it made a 90-degree turn to the west. Initial northward motion, with a later turn to the west, has been observed with tropical cyclones that form at very low latitude in a near-equatorial trough, and, although a physical understanding of why or how the event takes place is little understood, the operational forecaster needs to anticipate its occurrence.

In the process of becoming a super typhoon, Koryn went through a period of rapid intensification for a period of 36 hours (221800Z to 240600Z). The 66-mb fall of the central pressure over these 36 hours represents an average pressure fall of 1.83 mb/hr which exceeds the 1.75 mb per hour criteria established for rapid intensification by Holliday and Thompson (1979).

While crossing northern Luzon, Koryn's weakened 20 kt (10 m/sec) — from 110 kt (57 m/sec) to 90 kt (46 m/sec) — which is well below the expected 45 kt (23 m/sec) as discussed in Shoemaker (1991) and Williams et al (1993) (S&W). This may be due to Koryn's rapid forward motion of 15 kt (28 km/hr): the faster the forward motion the less the weakening — a factor found by S&W.


TROPICAL DEPRESSION 07W
BEST TRACK TC-07W
15 JUN - 20 JUN 93
MAX SFC WIND 30KT
MINIMUM SLP 1000MB
E 110
115
120
125
130
135
140
145 E
N 20
15
10
5
EQ
L-20/00Z
F-17/06Z
TCFA
ABPW
16c
17
18
19
20
5a
25b
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TROPICAL DEPRESSION 07W

I. HIGHLIGHTS

The final significant tropical cyclone of June, Tropical Depression 07W, was a short-lived system which formed in the monsoon trough east of Mindanao. After initially tracking northward, Tropical Depression 07W turned northwestward, crossed the central Philippines and dissipated (Figure 3-07-1).

II. CHRONOLOGY OF EVENTS

June

150600Z - The disturbance was first mentioned in the Significant Tropical Weather Advisory as an area of persistent convection within the monsoon trough.
170131Z - A Tropical Cyclone Formation Alert was issued following a consolidation of convection near the circulation center and a 20 kt (10 m/sec) ship report from the 161200Z surface streamline analysis.
170600Z - The first warning was issued based upon satellite intensity estimate of 25 kt (13 m/sec).
200000Z - The significant weakening of TD07W as it crossed the Philippine Islands prompted JTWC to cease warning on the system.

III. IMPACT

No reports received.

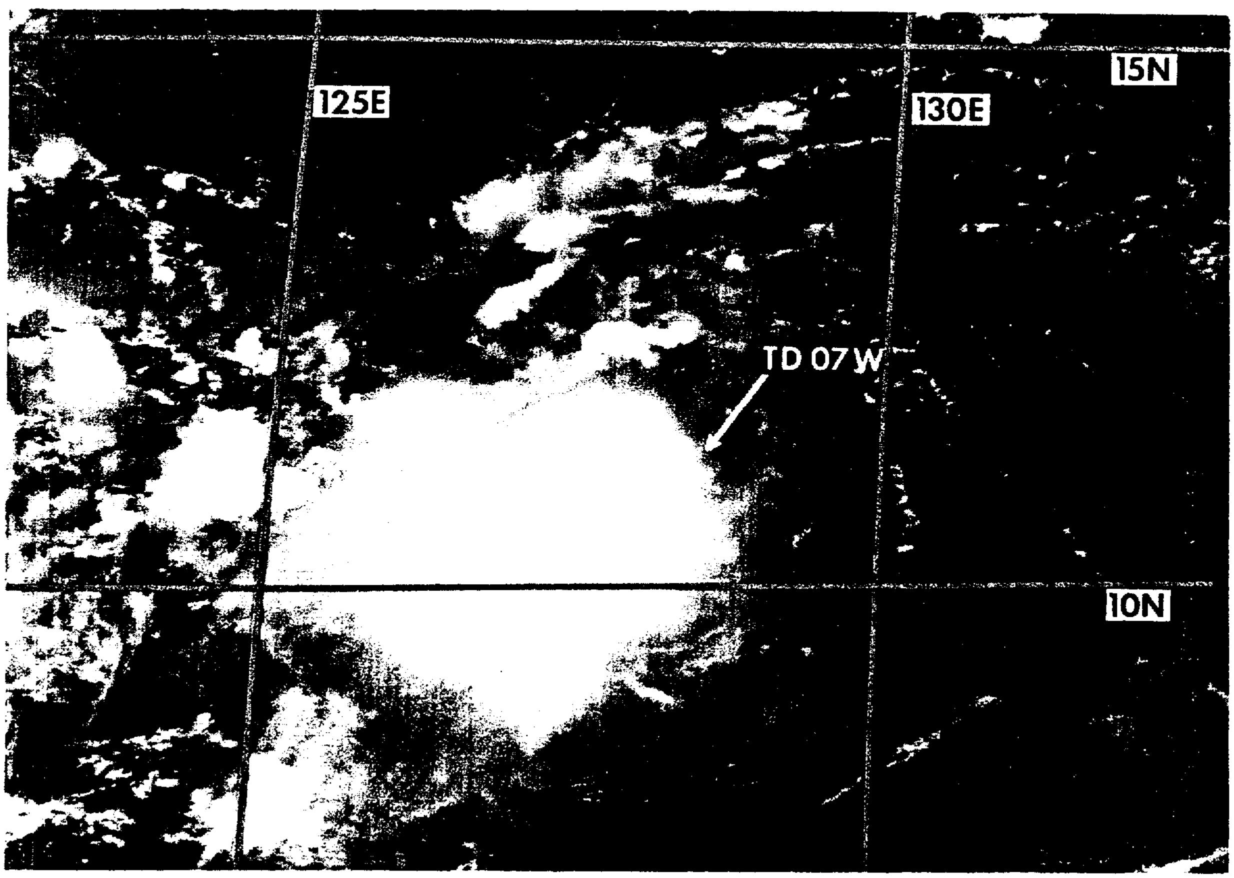
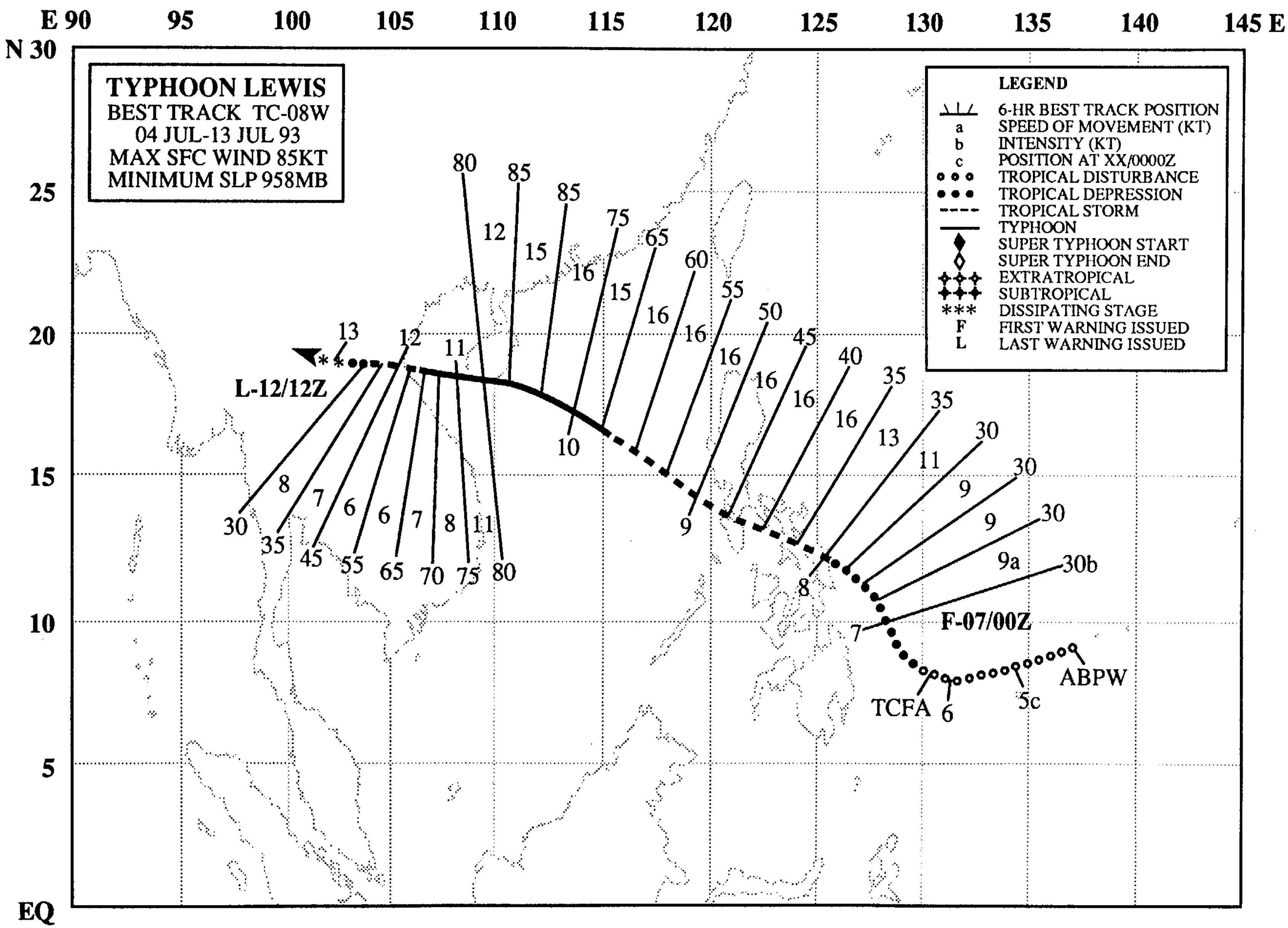


Figure 3-07-1 Approaching the central Philippines, TD 07W attains its peak intensity of 30 kt (15 m/sec)(180530Z June visual GMS imagery).


TYPHOON LEWIS
BEST TRACK TC-08W
04 JUL-13 JUL 93
MAX SFC WIND 85KT
MINIMUM SLP 958MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 90
95
100
105
110
115
120
125
130
135
140
145 E
N 30
25
20
15
10
5
EQ
L-12/12Z
F-07/00Z
TCFA
ABPW
9a
30b
5c

TYPHOON LEWIS (08W)

I. HIGHLIGHTS

Forming in the Philippine Sea, Typhoon Lewis was the first in a series of five significant tropical cyclones to occur during July. As it tracked west-northwestward, Lewis made landfall three times, over the central Philippines, Hainan Dao, and Vietnam, before dissipating over Thailand.

II. CHRONOLOGY OF EVENTS

July

040600Z - Persistent convection within the monsoon trough, east of the Philippine Islands, resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.

060630Z - A Tropical Cyclone Formation Alert was issued when satellite image animation revealed an increase in the amount and curvature of the convection.

070000Z - The first warning on Lewis was issued based upon the first daylight satellite image with an intensity estimate of 25 kt (13 m/sec).

081200Z - Following a synoptic report of 998.9 mb near the circulation center and supported by satellite intensity estimates, Lewis was upgraded to a tropical storm. Post analysis indicates Lewis most probably attained tropical storm intensity 12 hours earlier at 080000Z.

100000Z - Satellite intensity estimates of 65 kt (33 m/sec) resulted in Lewis being upgraded to a typhoon (Figure 3-08-1).

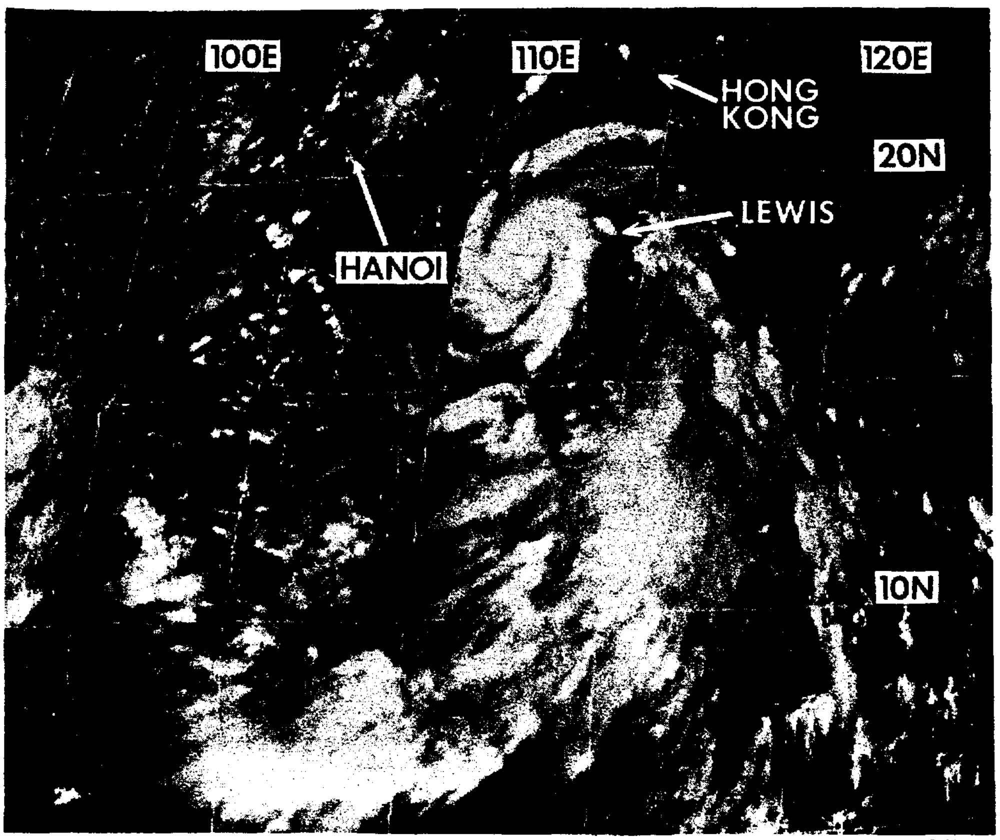
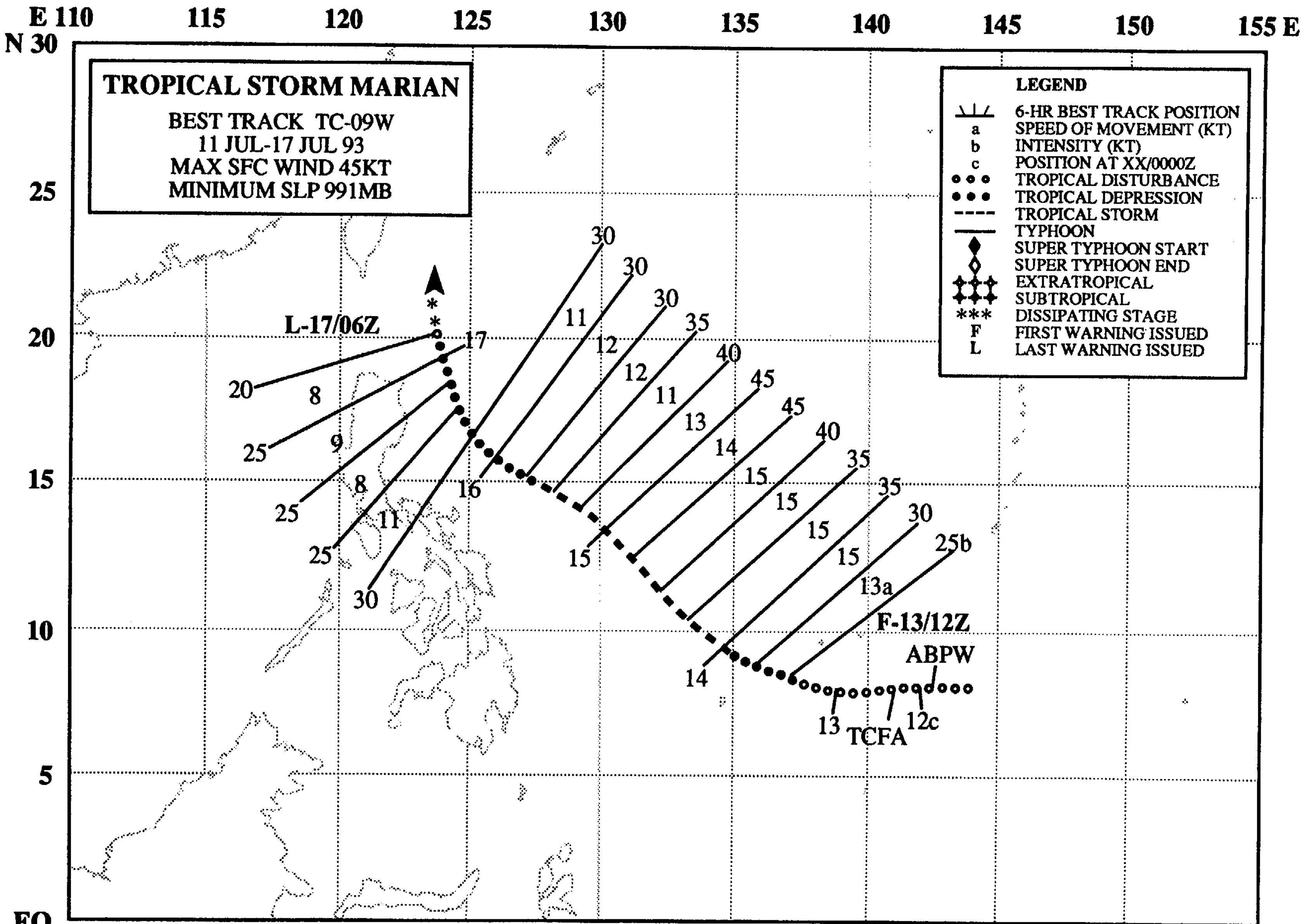


Figure 3-08-1 Tight coils of convection define Lewis shortly before the typhoon makes landfall on Hainan Dao (100530Z July visual GMS imagery).

121200Z - The final warning on Lewis was issued as the tropical cyclone rapidly weakened over the mountains of Southeast Asia.

III. IMPACT

News releases from Vietnam attributed two deaths, two injuries, and eight people missing to Lewis' passage. In northeast Thailand, flash floods damaged farmlands and more than 100 roads and bridges as the remnants of Lewis tracked westward.


TROPICAL STORM MARIAN
BEST TRACK TC-09W
11 JUL-17 JUL 93
MAX SFC WIND 45KT
MINIMUM SLP 991MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 110
115
120
125
130
135
140
145
150
155 E
N 30
25
20
15
10
5
EQ
L-17/06Z
F-13/12Z
ABPW
TCFA
13a
25b
12c

TROPICAL STORM MARIAN (09W)

I. HIGHLIGHTS

Forming within the monsoon trough, Marian tracked northwestward towards northern Luzon, then took a more northward track before dissipating in the Philippine Sea. Strong, persistent upper-level winds inhibited development and ultimately led to Tropical Storm Marian's dissipation.

II. CHRONOLOGY OF EVENTS

July

111900Z - A persistent convection embedded in the monsoon trough in the western Caroline Islands was first mentioned in the Significant Tropical Weather Advisory

120800Z - A Tropical Cyclone Formation Alert (TCFA) was issued following an increase in convective organization (Figure 3-09-1). Because the tropical disturbance was slow to develop, the TCFA with reissued 24 hours later.

131200Z - Rapidly improving convective organization resulted in a satellite intensity estimate of 25 kt (13 m/sec) which prompted JTWC to issue the first warning.

140000Z - Based upon a satellite intensity estimate of 35 kt (18 m/sec), Marian was upgraded to tropical

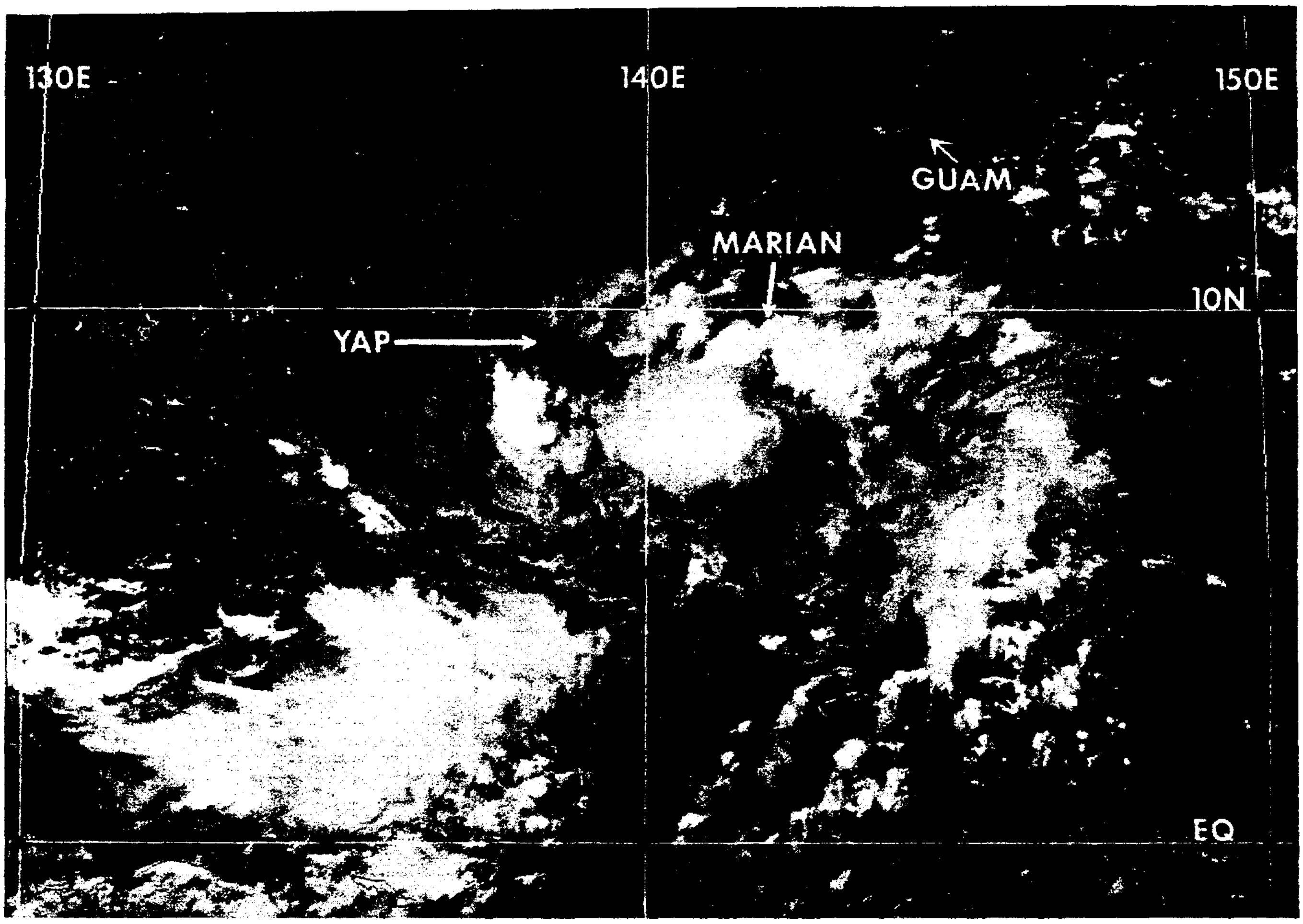
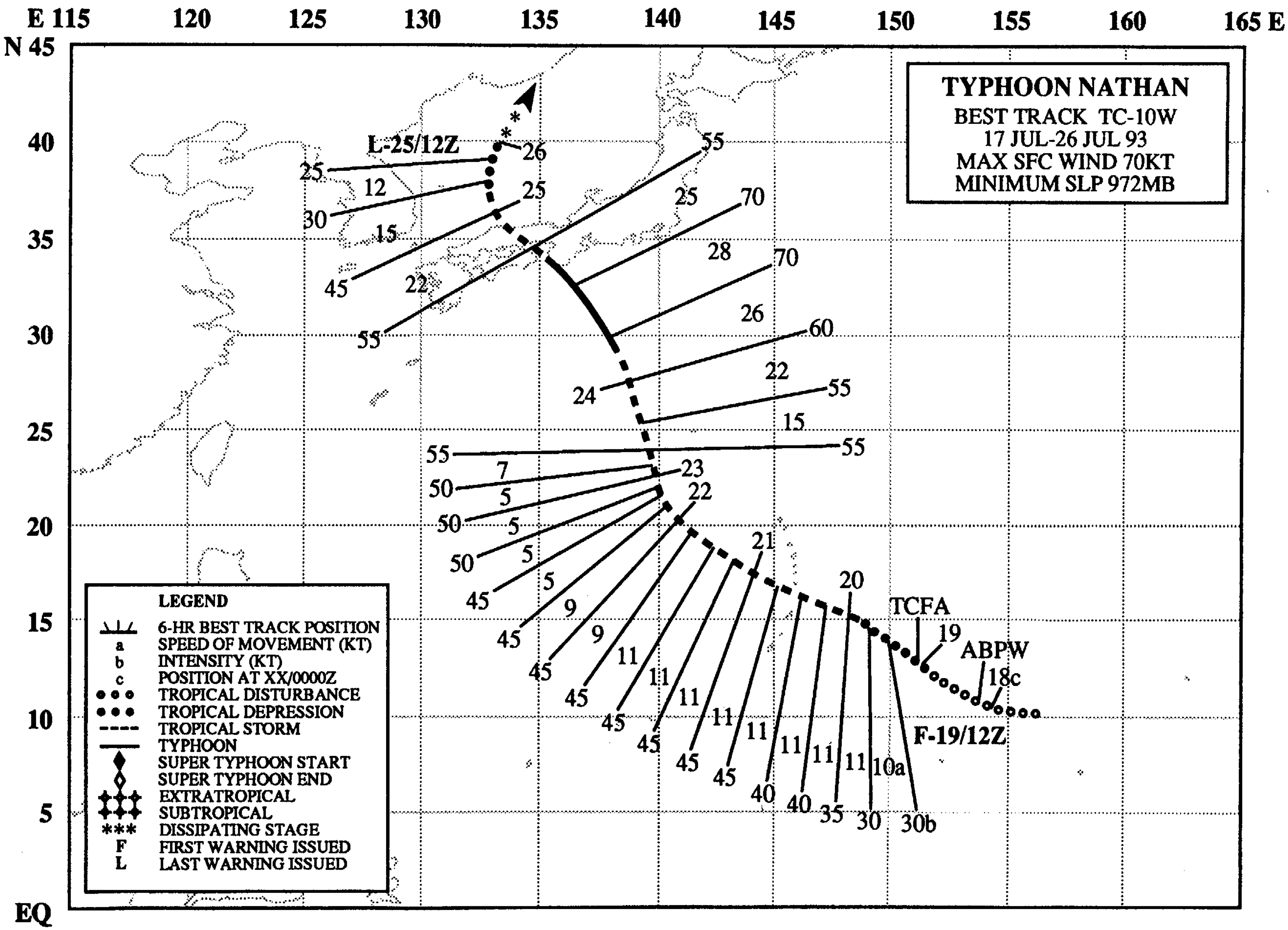


Figure 3-09-1 Marian, which is slowly intensifying, approaches the island of Yap (120425Z July visual GMS imagery).


TYPHOON NATHAN
BEST TRACK TC-10W
17 JUL-26 JUL 93
MAX SFC WIND 70KT
MINIMUM SLP 972MB
E 115
120
125
130
135
140
145
150
155
160
165 E
N 45
40
35
30
25
20
15
10
5
EQ
L-25/12Z
F-19/12Z
TCFA
ABPW
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON NATHAN (10W)

I. HIGHLIGHTS

After passing through the central Mariana Islands, Nathan interacted with a monsoon gyre which had formed in the Philippine Sea. Approaching the SW-NE oriented cloud band associated with the monsoon gyre, Nathan turned to the north to occupy a position at the northeastern end of that cloud band. From this position, Nathan accelerated rapidly (northward at first, then tending more northwesterly); and, breaking free of the monsoon cloud band, raced across southwestern Japan. Later, it entered the Sea of Japan, where it slowed in forward speed and dissipated. Operationally, Nathan was most notable for it's impact on Exercise Tandem Thrust in the Mariana Islands and it's rapid acceleration towards Japan. JTWC forecasts were hampered by the inability of the NOGAPS model to simultaneously handle a cutoff low south of Kyushu as Nathan rapidly approached Japan.

II. CHRONOLOGY OF EVENTS

July

170600Z - An area of persistent convection within the monsoon trough, northwest of Pohnpei, resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.

190200Z - An increase in both the amount and curvature of the convection east of the Mariana Islands, led to issuance of a Tropical Cyclone Formation Alert.

191200Z - Consolidation of central cloudiness and the resulting satellite intensity estimate of 25 kt (13 m/sec) prompted the first warning. Post analysis of satellite and synoptic data indicated that the formation of the tropical depression most probably occurred 12 hours earlier at 190000Z.

200000Z - Based upon a satellite intensity estimate of 35 kt (18 m/sec), Nathan was upgraded to a tropical storm.

240600Z - The appearance of a ragged, cloud-filled eye and a satellite intensity estimate of 77 kt (40 m/sec) led to Nathan's upgrade to a typhoon.

251200Z - The final warning was issued on Nathan as it dissipated in the Sea of Japan.

III. IMPACT

The approach of Tropical Storm Nathan towards Saipan and Tinian in the central Mariana Islands hindered operations during Exercise Tandem Thrust.

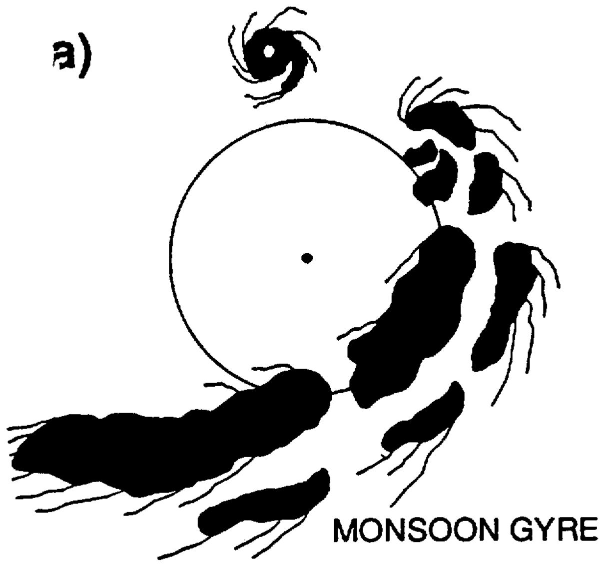
IV. DISCUSSION

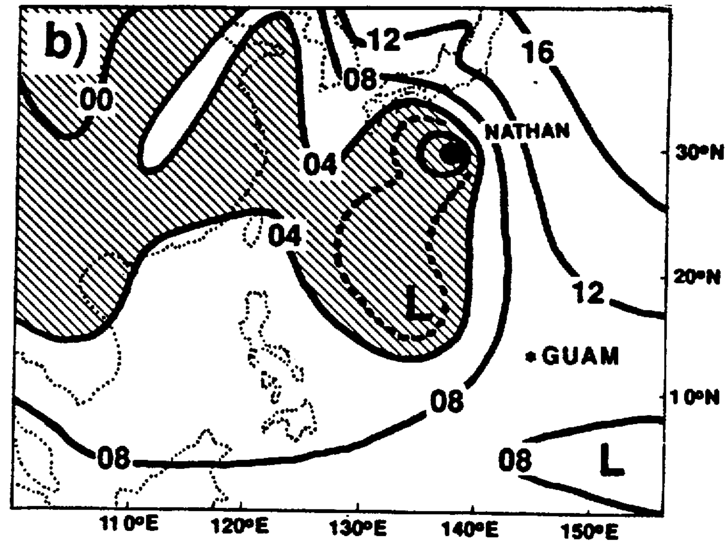
During the latter half of July 1993, the monsoon circulation of the western North Pacific became organized as a monsoon gyre (see definition in Appendix A and Figure 3-10-1). The monsoon gyre of July 1993 was associated with the formation of two and the motion of three very small tropical cyclones: Nathan, Ofelia (11W), and Percy (12W). Fortuitously, the Office of Naval Research and the Naval Postgraduate School were conducting a mini-field experiment, Tropical Cyclone Motion 1993 (TCM-93) (see Harr et al., 1993 for details), during the lifetime of this monsoon gyre. In support of TCM-93, an Air Force Reserve WC-130 weather reconnaissance aircraft from the 815th Weather Squadron was deployed to Guam to obtain measurements in and around tropical cyclones in the western North Pacific.

By 21 July, an independent large-scale cyclonic vortex had formed in the tropics of the western North Pacific. This vortex and its accompanying low-pressure area moved westward over the next 10

days, and influenced the motion of Nathan, Ofelia (11W), and Percy (12W). In each case, the tropical cyclone emerged from the downstream head of the monsoon cloud band, escaped from the gyre circulation and followed a "north-oriented" track (JMA, 1976) over Japan. Noted by Harr et al. (1993), each storm formed westward of the previous storm as the monsoon gyre drifted westward (Figure 3-10-2). By the first of August 1993, the monsoon gyre had merged with the low-pressure area over the Asian land mass.

During the westward migration of the July 1993 monsoon gyre, a successful forecast of sequential tropical cyclone development (each predicted to form to the west of the one prior) in the northeastern quadrant of the monsoon gyre was made by the TCM-93 forecast team in conjunction with JTWC forecasters. Three aircraft missions were flown during the period of genesis and intensification of the second gyre-related tropical cyclone, Ofelia (see Harr et al., 1993). The TCM-93 data set may provide a means to examine the mechanisms leading to the formation of midget or very small tropical cyclones in the peripheral cloud band of a monsoon gyre.





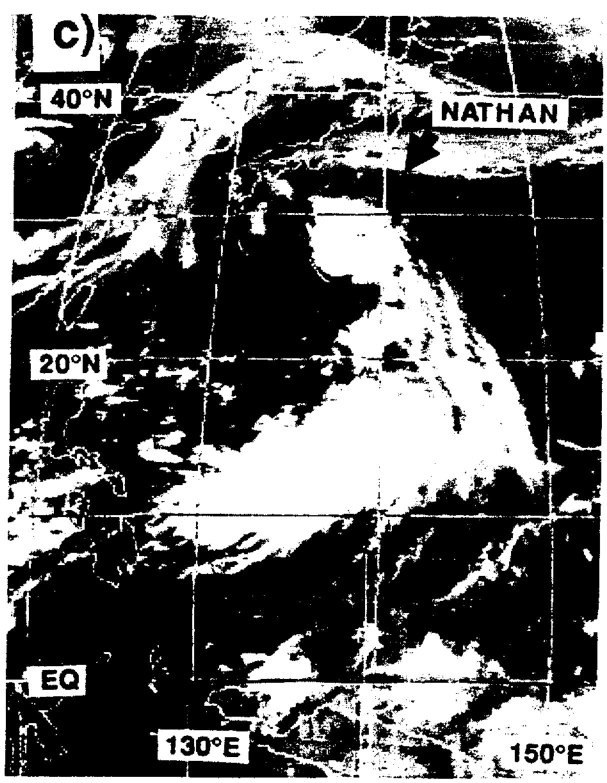


Figure 3-10-1 Depiction of a monsoon gyre. a) Schematic illustration of a monsoon gyre's cloudiness and pressure. Solid black cloud silhouettes represent areas of deep convective, single filaments indicate cirrus orientation and the circle depicts the region of large-scale lowest surface pressure surrounding the center (dot) of the monsoon gyre. b) Surface pressure analysis for 240600Z July of Nathan embedded in a monsoon gyre. Pressure contours are every 4 mb with areas of 1004 mb or less hatched. c) 240000Z July infrared GMS image of Nathan and cloudiness associated with a monsoon gyre.

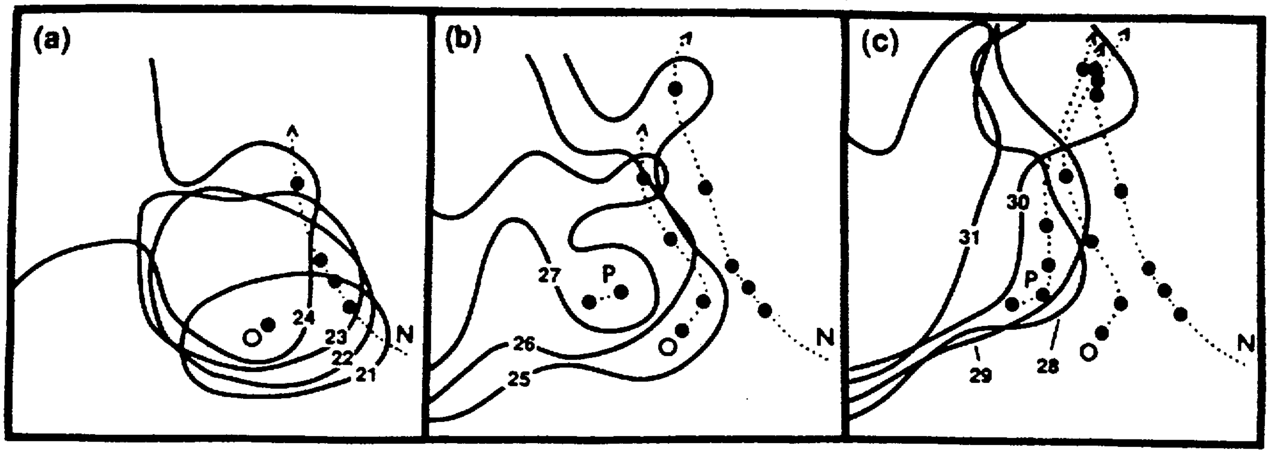
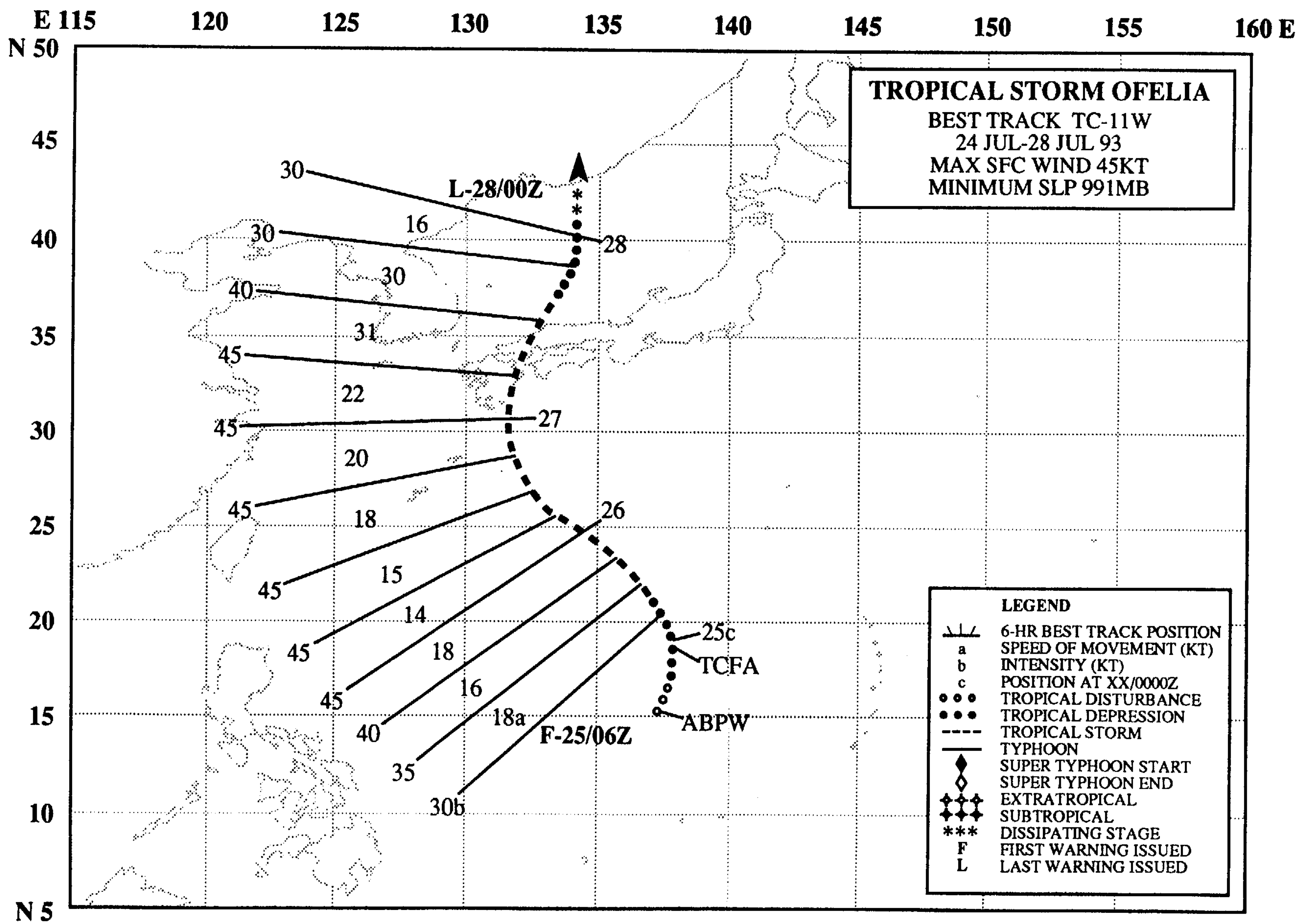


Figure 3-10-2 Illustration of the west-northwestward movement of the monsoon gyre of July 1993. a) The 1008, 1008, 1006 and 1004 mb contour of sea-level pressure (SLP) at 06Z July 21, 22, 23 and 24 respectively. b) The 1006 mb contour of SLP at 06Z July 25, 26 and 27. c) The 1006 mb contour of SLP at 067Z July 28, 29, 30 and 31. Dots show 06Z position of Nathan (N), Ofelia (O) and Percy (P) which show on each panel.


TROPICAL STORM OFELIA
BEST TRACK TC-11W
24 JUL-28 JUL 93
MAX SFC WIND 45KT
MINIMUM SLP 991MB
E 115
120
125
130
135
140
145
150
155
160 E
N 50
45
40
35
30
25
20
15
10
N 5
L-28/00Z
F-25/06Z
28
27
26
25c
TCFA
ABPW
30b
18a
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TROPICAL STORM OFELIA (11W)

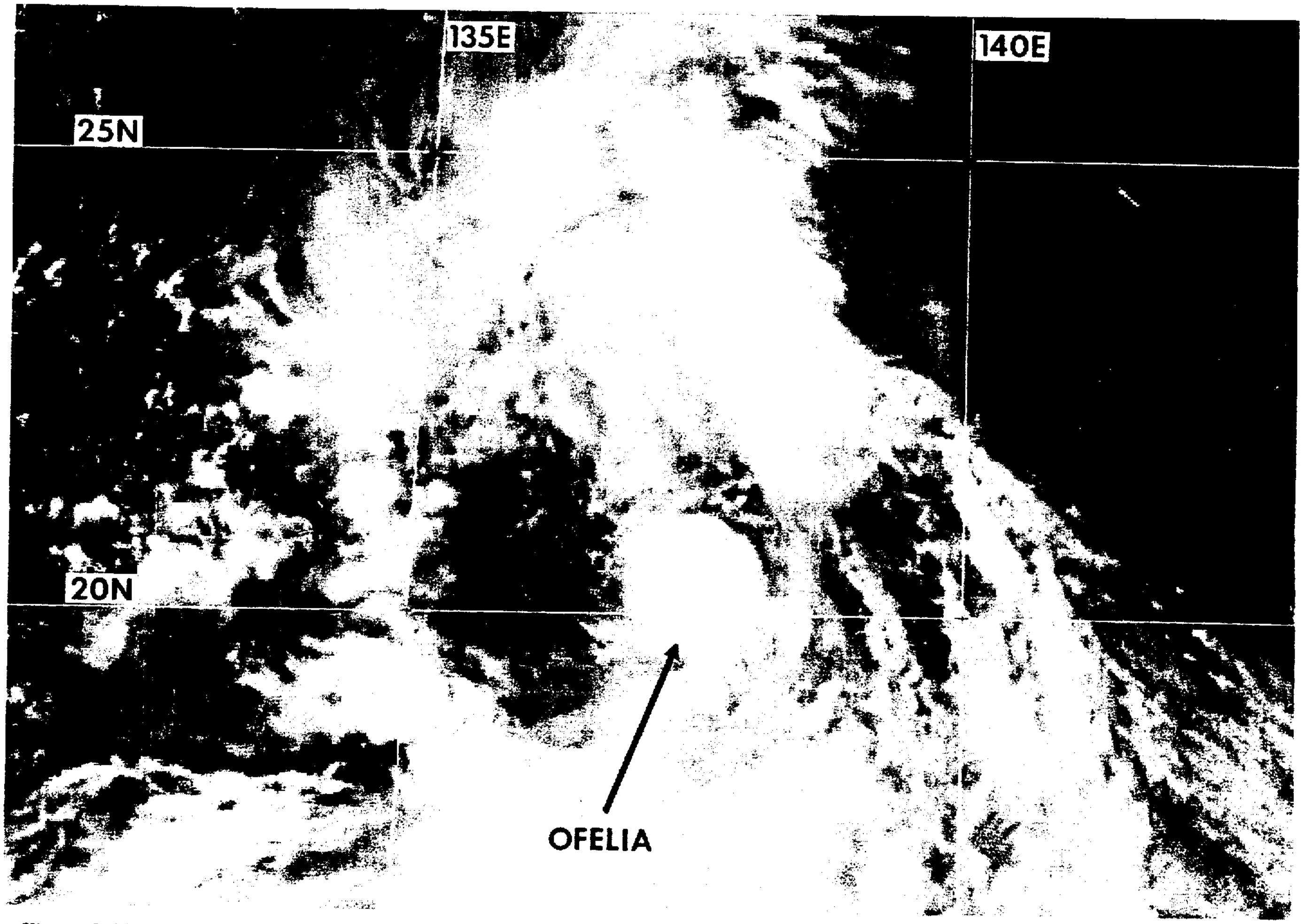


Figure 3-11-1 Ofelia with a rapidly developing CDO begins its separation from the monsoon cloud band (250531Z July visual GMS imagery).

I. HIGHLIGHTS

Forming in association with a monsoon gyre, Ofelia was the only system not to attain typhoon intensity during July. Ofelia was of interest due to its unusually rapid initial development and small size (Figure 3-11-1). Because of TCM-93, valuable additional data from Air Force aircraft weather reconnaissance describing this tropical cyclone were available to JTWC forecasters.

II. CHRONOLOGY OF EVENTS

July

240600Z - The disturbance was first mentioned in the Significant Tropical Weather Advisory as an area of persistent convection in the Philippine Sea.

242200Z - A Tropical Cyclone Formation Alert was issued based upon the first daylight visual satellite image showing a well organized exposed low-level circulation center.

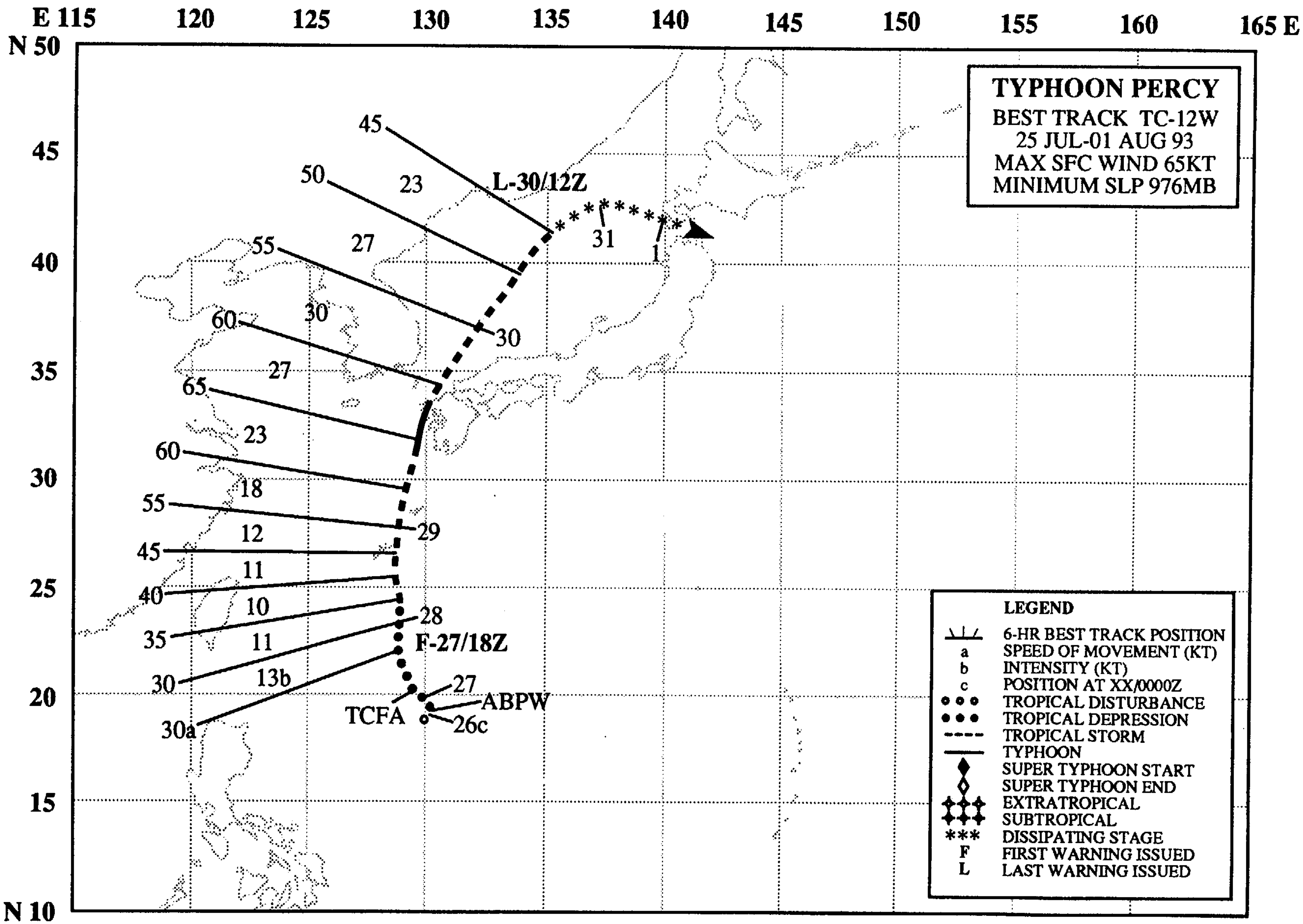
250600Z - Due to the unusually rapid growth of a central dense overcast (CDO) over the low-level circulation center, the first warning was issued for a tropical storm. Post analysis indicated that Ofelia

most probably reached tropical storm intensity at 250900Z.

280000Z - The final warning was issued as Ofelia dissipated over the Sea of Japan.

III. IMPACT

No reports received.


TYPHOON PERCY
BEST TRACK TC-12W
25 JUL-01 AUG 93
MAX SFC WIND 65KT
MINIMUM SLP 976MB
E 115
120
125
130
135
140
145
150
155
160
165 E
N 50
45
40
35
30
25
20
15
N 10
L-30/12Z
F-27/18Z
TCFA
ABPW
26c
27
28
29
30
31
1
30a
13b
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON PERCY (12W)

I. HIGHLIGHTS

The final significant tropical cyclone to spin out of a monsoon gyre, Typhoon Percy, also followed a north-oriented track towards Japan. Forming in the Philippine Sea, Percy briefly attained typhoon intensity, but was most notable for it's rapid acceleration towards Japan after passing near Okinawa (Figure 3-12-1).

II. CHRONOLOGY OF EVENTS

July

260600Z - An area of persistent convection, which separated from a large area of deep convection associated with converging monsoonal flow into Tropical Storm Ofelia (11W), resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.

270600Z - A Tropical Cyclone Formation Alert was issued as monsoonal wind flow across the Philippine Sea enhanced convection associated with the disturbance.

271800Z - The first warning was issued based upon a consolidation of convection near the circulation center and a satellite intensity estimate of 25 kt (13 m/sec).

280600Z - Based upon a synoptic report, which indicated 25 kt (13 m/sec) southerly winds located 60 nm (111 km) from the circulation center, Percy was upgraded to a tropical storm.

291200Z - The appearance of a cloud filled eye and the resulting satellite intensity estimate of 65 kt (33 m/sec) prompted the upgrade to a typhoon.

301200Z - The final warning was issued on Percy as it dissipated in the Sea of Japan.

III. IMPACT

The highest reported wind gusts on Okinawa — 49 kt (25 m/sec) — occurred at Naha (WMO 47936). Later, Amami, Japan (WMO 47909), in the northern Ryukyu Islands, reported maximum wind gusts of 69 kt (36 m/sec). No reports of damage were received.

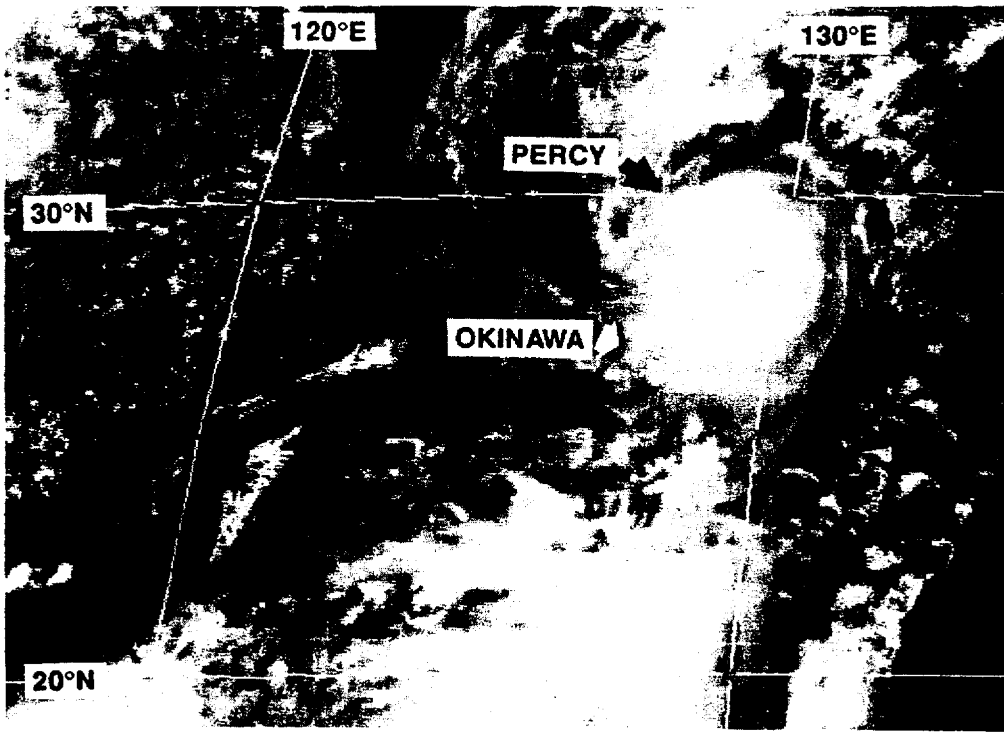
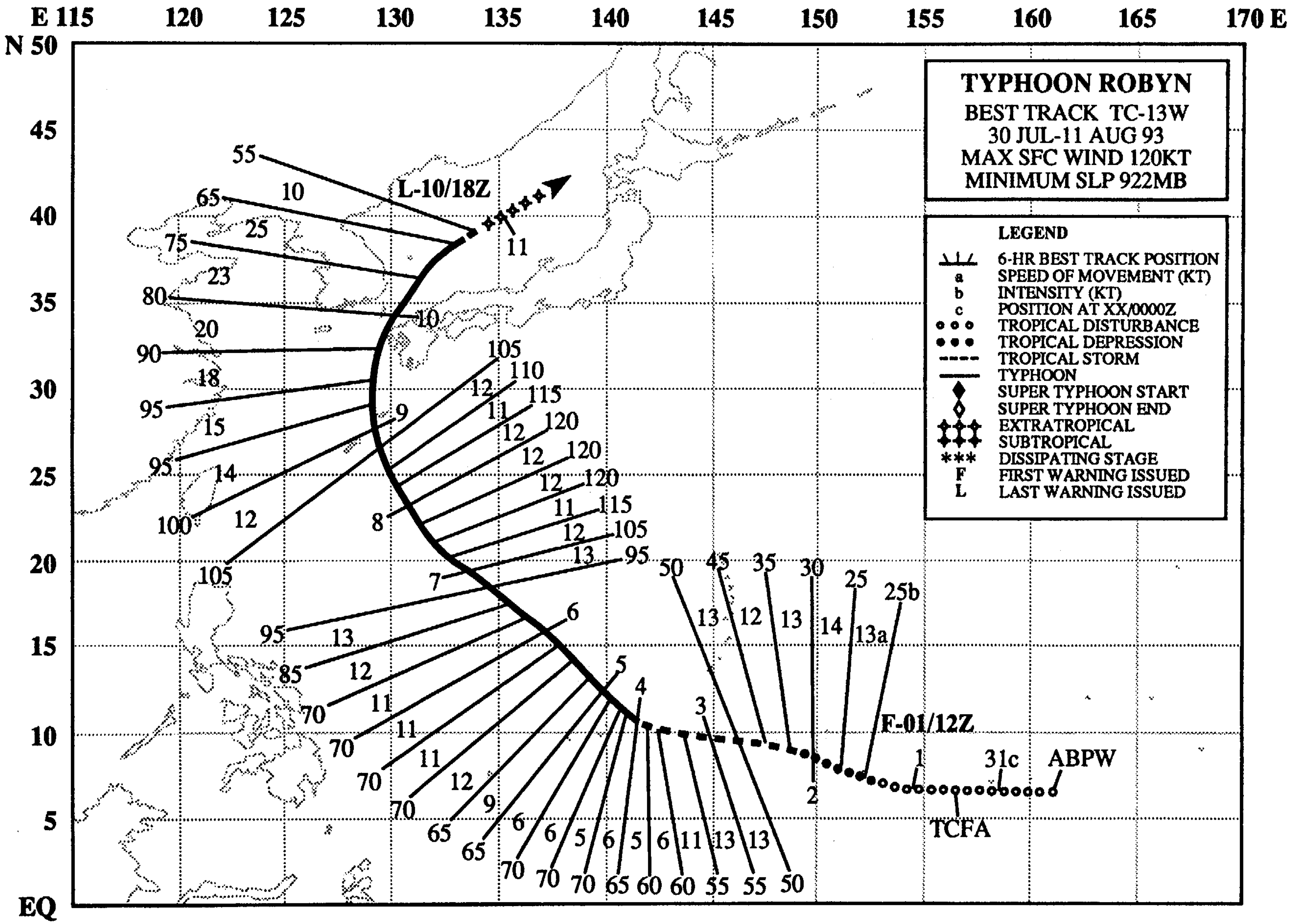


Figure 3-12-1 Percy brushes by Okinawa (290424Z July visual GMS imagery).



E 115
120
125
130
135
140
145
150
155
160
165
170 E
N 50
45
40
35
30
25
20
15
10
5
EQ
TYPHOON ROBYN
BEST TRACK TC-13W
30 JUL-11 AUG 93
MAX SFC WIND 120KT
MINIMUM SLP 922MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-10/18Z
F-01/12Z
TCFA
ABPW

TYPHOON ROBYN (13W)

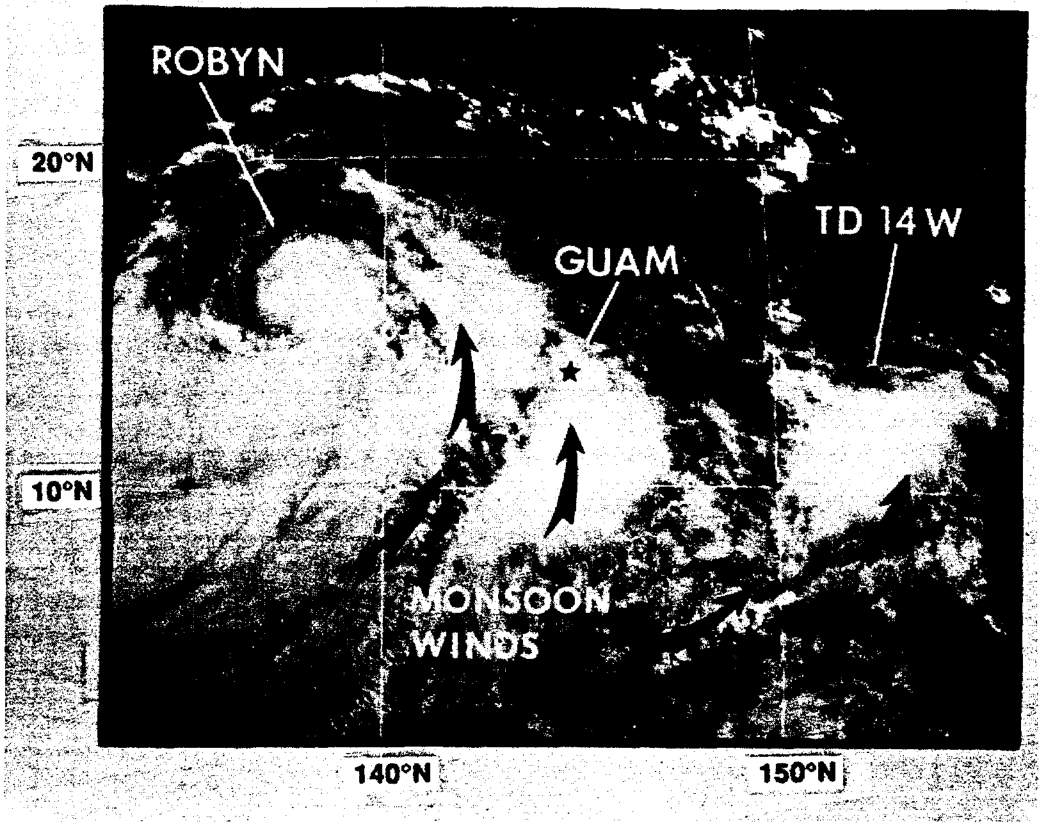


Figure 3-13-1 Typhoon Robyn with its associated rain and monsoon southwesterly winds churns northwestward towards Ryukyu Islands (052224Z August visual GMS Imagery).

I. HIGHLIGHTS

The sixth and final tropical cyclone of July, Robyn, formed in the near equatorial trough in the eastern Caroline Islands. This typhoon was notable for its large size, and for the fact that it was one of three to impact both Okinawa and Sasebo, Japan in 1993. Data from a WC-130 weather reconnaissance aircraft flying in support of TCM-93 were used to support tracking and forecasting.

II. CHRONOLOGY OF EVENTS

July

300600Z - An area of persistent convection in the near equatorial trough resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory..

311300Z - A Tropical Cyclone Formation Alert was issued based on indications from animated satellite imagery, synoptic reports and weather reconnaissance observations that a cyclonic circulation was developing.

August

011200Z - The first warning was issued based on a satellite intensity estimate of 25 kt (13 m/sec).

020600Z - Based on a satellite intensity estimate of 35 kt (18 m/sec), Robyn was upgraded to a tropical storm, about 250 nm (463 km) northwest of Chuuk.

030600Z - Based on a satellite intensity estimate of 65 kt (33 m/sec), Robyn was upgraded to a typhoon.

Post analysis of subsequent satellite and aircraft data indicated that the system most probably reached typhoon intensity at 040000Z.

080835Z - The JTWC transferred warning responsibility for Robyn to the AJTWC at Pearl Harbor, Hawaii after an 8.1 magnitude earthquake centered near Guam interrupted power and communications at JTWC.

082130Z - The JTWC resumed warning responsibility.

101800Z - The final warning was issued on Robyn as it rapidly weakened and transitioned into an extratropical low.

III. IMPACT

As Robyn moved southwest of Guam, it provided some relief for the drought-stricken island. Typhoon Robyn caused Condition of Readiness (COR) 1 to be set at Ulithi and Yap. JTWC forecasters expected the system to turn northward, but that the timing could not be determined accurately enough to keep Yap from setting COR 1. After passing to the north of Ulithi and Yap, Robyn (Figure 3-13-1) headed for the Ryukyu Islands. Kadena AB, on Okinawa evacuated aircraft and went to COR 1 at 080300Z. Peak winds recorded on Okinawa were 43 kt (22 m/sec). Subsequently, Robyn tracked across Kyushu, causing the Naval Station at Sasebo, Japan to set COR 1. As Robyn passed just west of the Sasebo, a ship in the harbor, the MV Maersk Constellation, reported sustained winds of 60-65 kt (31-33 m/sec) and a barometric pressure of 973 mb at 091800Z. The ship's pressure fell to a minimum of 969.0 mb at 092200Z. During the ordeal, the ship dragged anchor for half a mile across the harbor. In contrast, the Sasebo weather station which is sheltered by hills only reported maximum sustained winds of 40-48 kt (21-25 m/sec) with gusts to 60 kt (31m/sec). Later, as Robyn passed though the Korea Strait, it created 20-35 ft (6.1-10.7 m) waves on the southern coast of Korea. Coastal wave damage and agricultural losses due to flooding amounted to more than (US)$68 million. Of the over 45 storm-related deaths, press reports indicated 39 resulted from automobile accidents attributed to the torrential rains.

IV. DISCUSSION

The JTWC-based, month-long TCM-93 was in progress when Robyn began developing. The experiment team was using a WC-130 weather reconnaissance aircraft to test hypotheses involving sub-synoptic and mesoscale effects on tropical cyclone motion. In the case of Robyn, the team planned to test the hypothesis of Holland and Lander (H&L) (1993) that large mesoscale convective systems (MCS) embedded in the tropical cyclone circulation can cause meanders in tropical cyclone tracks on the order of 100 km over a period of 1-2 days. H&L's physical explanation for this is that an MCS develops sufficient vorticity, allowing it to rotate cyclonically with the tropical cyclone about a centroid between the two, in a manner similar to that observed during a Fujiwhara (or binary) interaction between two independent tropical cyclones. At 1230Z on the night of 03 August, a band of convection began to build about 100 nm (185 km) north of Robyn's central dense overcast (CDO). In two hours, a portion of the band had explosively expanded into a large elliptical MCS of comparable size to Robyn's CDO (Figure 3-13-2). Over the 9-hour period from 031500Z to 040000Z, the large MCS rapidly moved 300 nm (555 km) westward (from an initial location to the north of Robyn to a later position to the northwest of Robyn), at a speed of 34 kt (63 km/hr). During the same 9-hour period, Robyn slowed in forward speed from 13 kt (24 km/hr) to 6 kt (11 km/hr). After the MCS moved to the west side of Robyn, the typhoon's track, at least in the animated satellite imagery, appeared to cease all westward movement, take a small dip to the south, and then reverse direction, heading to the north and then the northwest.

This abrupt track change required less than 6 hours. The sequence of events concerning Typhoon Robyn are discussed in more detail in Harr et. al (1993).

Another plausible explanation for the unusual motion of Robyn has been postulated by Carr and Elsberry (C&E) (1994), who attributed the behavior to the interaction of Robyn with a large "monsoon gyre" located to its west. In sensitivity studies using a barotropic model, C&E were able to duplicate the character of Robyn's abrupt track changes — westward motion followed by an abrupt change to northward or northwestward motion. Figure 3-13-3 illustrates the sudden track changes exhibited by 6 tropical cyclones in 1990. It is conceivable that both the MCS and monsoon gyre mechanisms may have been working in tandem to produce Robyn's abrupt track change.

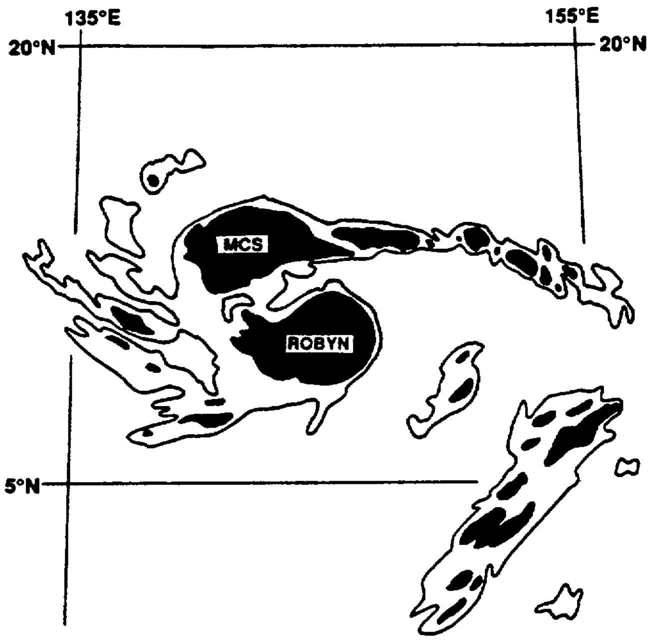


Figure 3-13-2 Graphic representation of the observed cold cloudiness associated with Robyn's CDO and an MCS. Solid black cloud silhouettes represent areas of coldest convective tops, outer contours shows regions of dense cirrus overcast. (Adapted from 031531Z August enhanced infrared GMS imagery.)

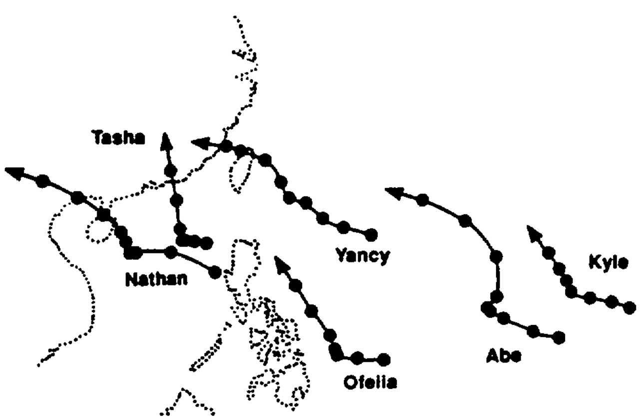
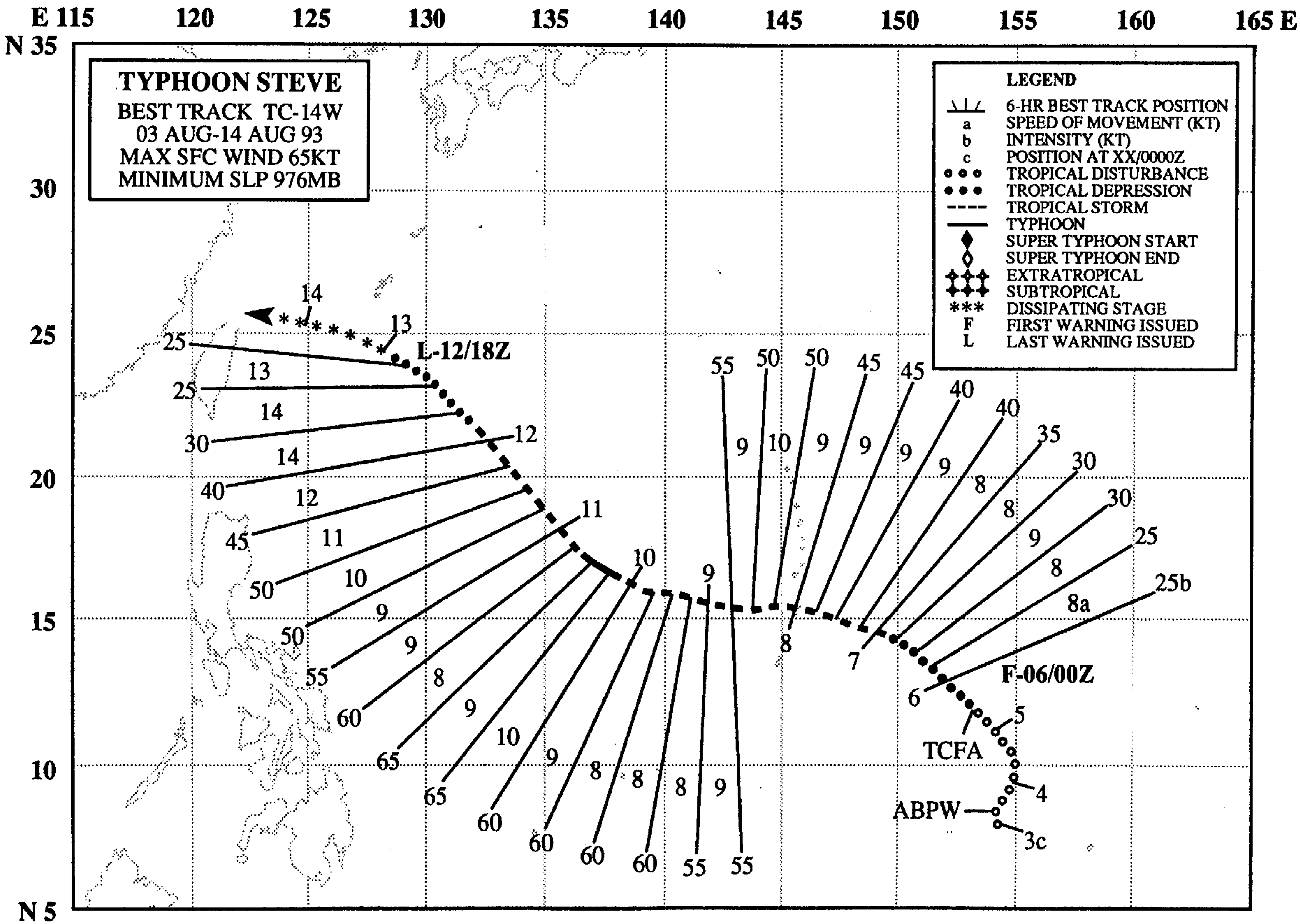


Figure 3-13-3 A composite of 3-4 day track segments centered around sudden below-the-ridge track changes for 6 tropical cyclones in 1990 (from Carr and Elsberry, 1994).



E 115
120
125
130
135
140
145
150
155
160
165 E
N 35
30
25
20
15
10
N 5
TYPHOON STEVE
BEST TRACK TC-14W
03 AUG-14 AUG 93
MAX SFC WIND 65KT
MINIMUM SLP 976MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-12/18Z
F-06/00Z
TCFA
ABPW
3c
25b
8a

TYPHOON STEVE (14W)

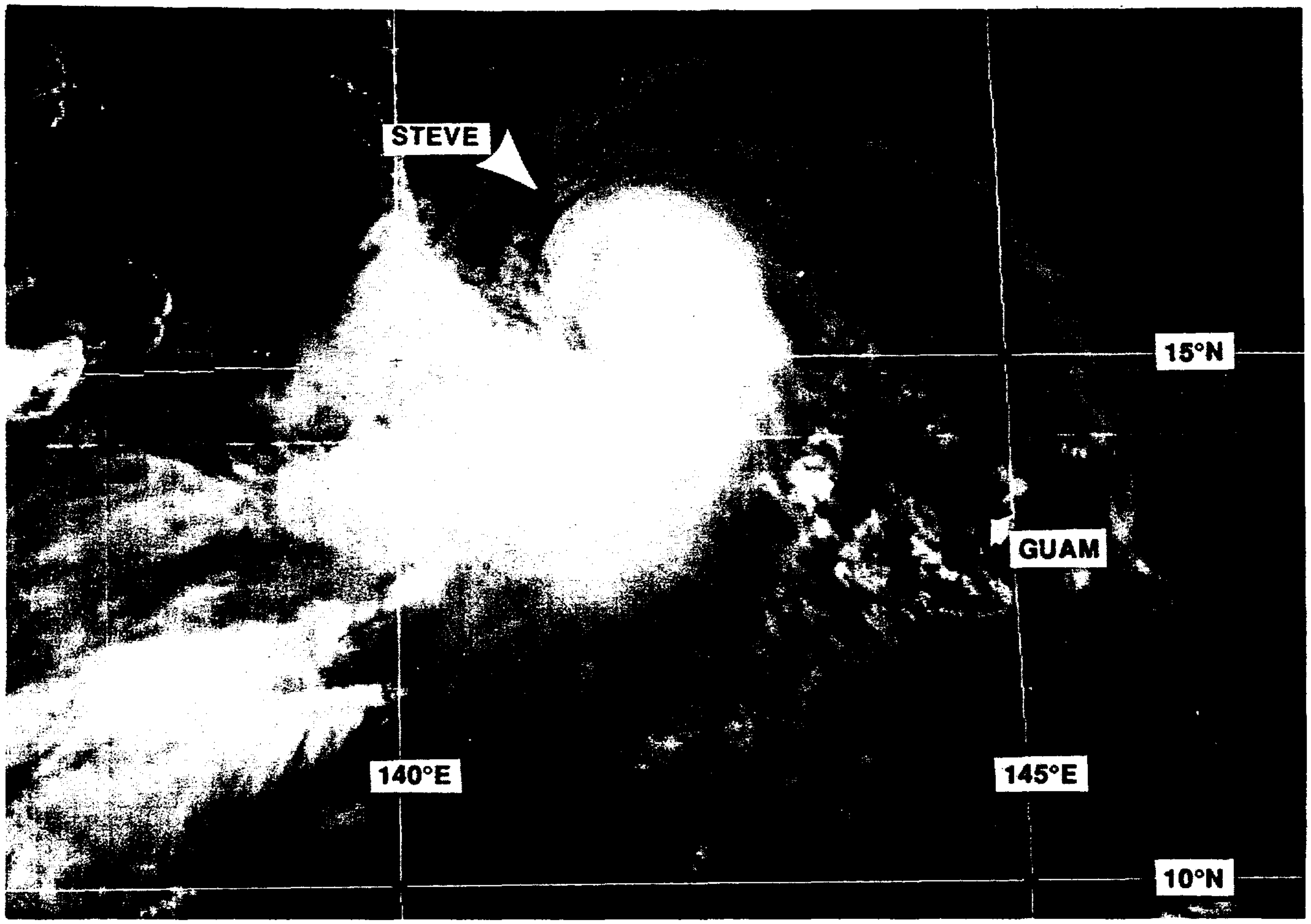


Figure 3-14-1 To the northwest of Guam, Steve continues to slowly intensify (082331Z August visual GMS imagery).

I. HIGHLIGHTS

Forming in the wake of, Robyn (13W), Steve became the second tropical cyclone of August. Despite the appearance of strong upper-level westerly wind shear from Robyn's outflow, Steve was able to attain minimal typhoon intensity. Later, however, the typhoon was subjected to strong easterly shear and rapidly dissipated over the open ocean south of Okinawa.

I. CHRONOLOGY OF EVENTS

August

030600Z - The tropical disturbance was first mentioned on the Significant Tropical Weather advisory as an area of persistent convection enhanced by a surge in the southwest monsoon.

051300Z - The appearance of a developing cyclonic circulation on the animated cloud imagery prompted the issuance of a Tropical Cyclone Formation Alert.

060000Z - The first warning was issued based on the improved organization of the convection as viewed on the the first visual satellite image of the day.

070000Z - Steve was upgraded to tropical storm intensity based on improved convective organization and the resulting 35-kt (13-m/sec) satellite intensity estimate.

080835Z - Warning responsibility transferred to the Alternate Joint Typhoon Warning Center at Pearl Harbor, Hawaii after an 8.1 magnitude earthquake near Guam temporarily knocked out power and communications.
081800Z - Warning responsibility returns to JTWC.
100600Z - Steve was upgraded to typhoon intensity based on the appearance of a cloud-filled eye.
121800Z - The final warning was issued on Steve following rapid dissipation over water in an environment featuring strong upper-level easterly winds.

III. IMPACT

Tropical Storm Steve caused Saipan and Tinian to go to Condition of Readiness (COR) 1. Saipan recorded sustained winds of 45 kt (23 m/sec) with gusts to 60 kt (31 m/sec) and experienced extensive flooding on the island due to heavy rains on 8 August. The large PACOM combined exercise, TANDEM THRUST, was prematurely ended when troops prepositioned on the island of Tinian were evacuated and a planned amphibious assault of the island was canceled due Steve's approach.

IV. DISCUSSION

As Steve developed and moved westward, it came under the upper-level outflow of Typhoon Robyn (13W). Despite the appearance of strong upper-level wind shear, Steve managed to continue to slowly intensify. As Robyn moved northwestward toward the Ryukyu Islands, the upper-level shear appeared to weaken as Steve slowly intensified (Figure 3-14-1). On the afternoon of 10 August, Steve was upgraded to typhoon intensity and coincidently made a track change from westward to northwestward. After reaching minimal typhoon intensity, Steve began to weaken apparently in association with the establishment of northeasterly flow aloft. This flow became established as Robyn recurved into midlatitudes and a large upper-level anticyclone formed east of Japan.

It is interesting to note that Steve intensified slowly in an environment that featured upper-level westerly winds, but weakened rapidly in an environment that featured upper-level northeasterly winds. A closer look at these two upper-level wind regimes follows.

a. Intensification despite westerly wind shear — Steve comes under the influence of the outflow from Typhoon Robyn. The fact that Steve is able to maintain a central dense overcast (CDO), suggests that the system's own outflow is able to hold its own against that of Robyn's, thus deflecting the westerly winds and preventing the shear from reaching the central core. It is suggested that in order for Steve to survive, its outflow has to maintain a buffer sufficient to keep the westerly winds from disrupting the vertical structure of the core of the storm. The deflection of the westerly upper-level winds around Steve's cloud system may not be as difficult as it would appear at first glance. The wind at 200 mb near Robyn was strongly cyclonic for a radius of several hundred miles. Thus, the upper-level westerly winds (as indicated by the orientation of the cirrus cloud plumes) in the vicinity of Steve — located downstream from Robyn's outflow to the east — were probably relatively high and relatively shallow. The thinness of the ambient cirrus is further evidence that the upper-level westerly flow over Steve was relatively high (at the 200-mb pressure height and higher) and shallow (confined between the 200-mb level upward to just above the tropopause). The relatively straight-line westerly winds from the high-level outflow streaming from Robyn and across the region of Steve lasted for three days (5-7 August) in the manner illustrated in the model in Figure 3-14-2a. There was a gradual shrinking of the convection in response to the shear during those three days (Figure 3-14-3a). By 8 August, the upper-level flow had become strongly diffluent in the region of Steve, flowing northward into a cell in the TUTT to the

northwest of Steve, and turning anticyclonically into strong easterlies south of Steve. This diffluent pattern is illustrated in the synoptic model in Figure 3-14-2b. Steve was thus placed in an area of maximum anticyclonic curvature which not only reduced the shear above the storm, but also placed Steve in a region of upper-level divergence — two factors commonly believed to be favorable for intensification. While all the shear was probably not eradicated, it was sufficiently reduced for a long-enough period of time to allow Steve to survive, and to grow in size and intensity as illustrated by the size of the cirrus shield in Figure 3-14-3b.

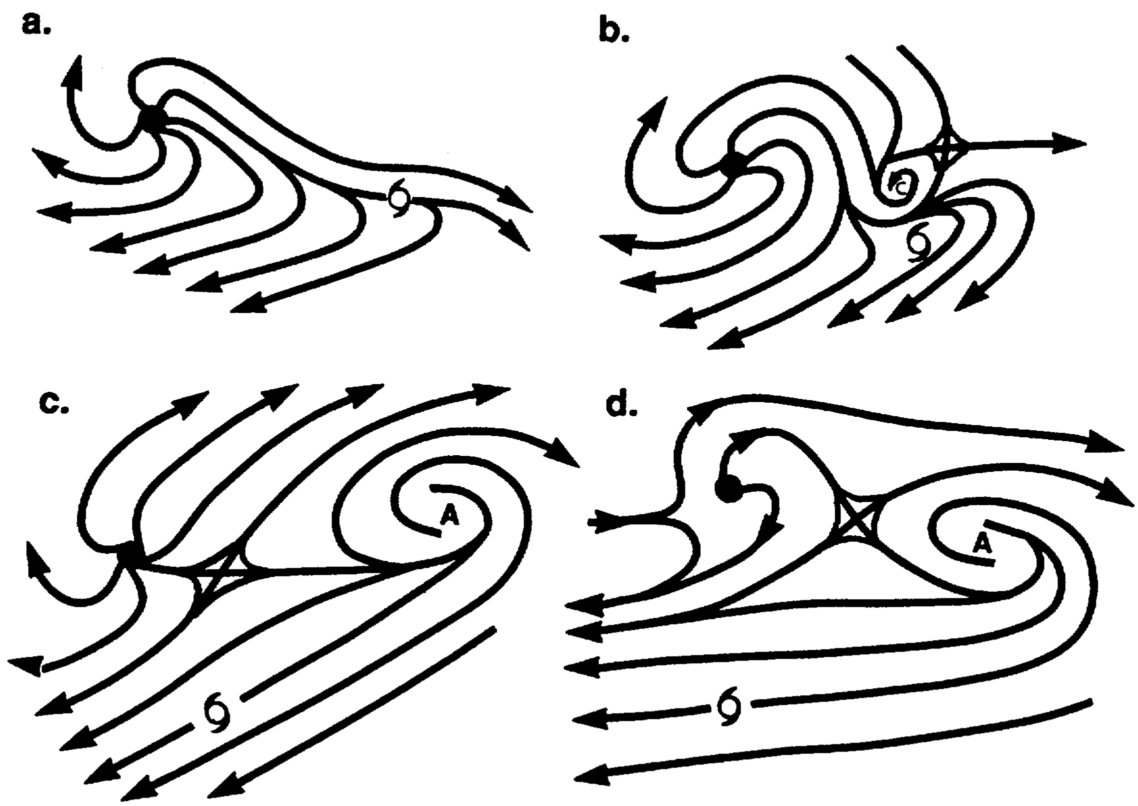


Figure 3-14-2 A model of upper-level streamlines based on composited 200-mb winds and cirrus plume orientations taken from satellite imagery associated with Robyn (13W) and Steve: (a) Composite for 5 through 7 August, (b) Composite for 8 through 10 August, (c) Composite for 10 and 11 August, and (d) Composite for 12 and 13 August. Solid black dot = the location of Robyn and tropical cyclone symbol = Steve.

b. Weakening with Strong Upper-Level Easterly Winds — In this case, the ambient flow is deep and non-diffluent easterly with speed increasing with height (Figure 3-14-2c and d). The easterly winds also act to block any outflow to the poleward side of the storm. The result is no intensification and eventual weakening. It is common to observe the decoupling of the convection and the low-level circulation, with the convection going in one direction and the exposed low-level circulation center going in another, as was observed with Steve. While subjected to strong upper-level northeasterly wind (later veering to easterly), the size of Steve's cirrus shield rapidly shrank (Figure 3-14-3c). Steve could not maintain its vertical structure against easterly winds aloft.

c. Rules of Thumb — 1) Upper-level westerly or southwesterly winds from a tropical cyclone can create a downstream environment to the east that is favorable for the development or intensification of another tropical cyclone, despite the appearance (on satellite imagery) of strong westerly shear across

the downstream tropical cyclone. The upper-level westerly winds are generally in a shallow layer, high, and strongly diffluent. Convection is favored at the location of the second (or downstream) tropical cyclone as a quasi-stationary trough amplifies in the upper-level flow between the two tropical cyclones. 2) In contrast, strong easterly or northeasterly upper-level winds across a tropical cyclone tend to shear away the convection leaving the low-level circulation center exposed.

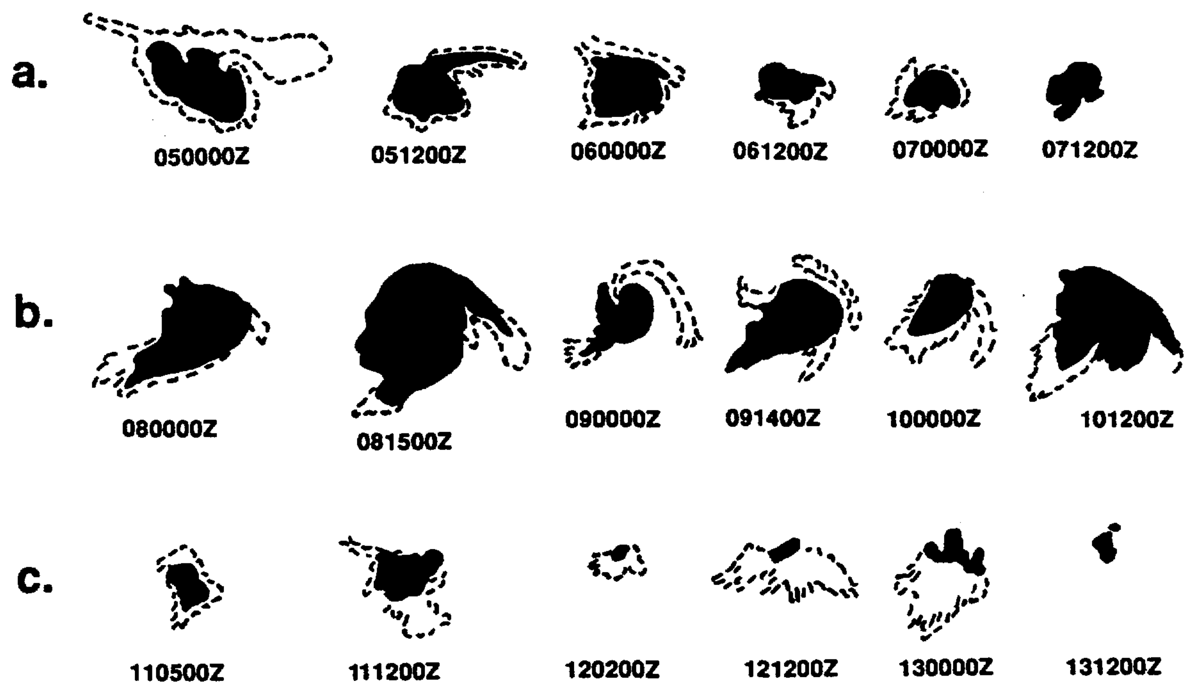
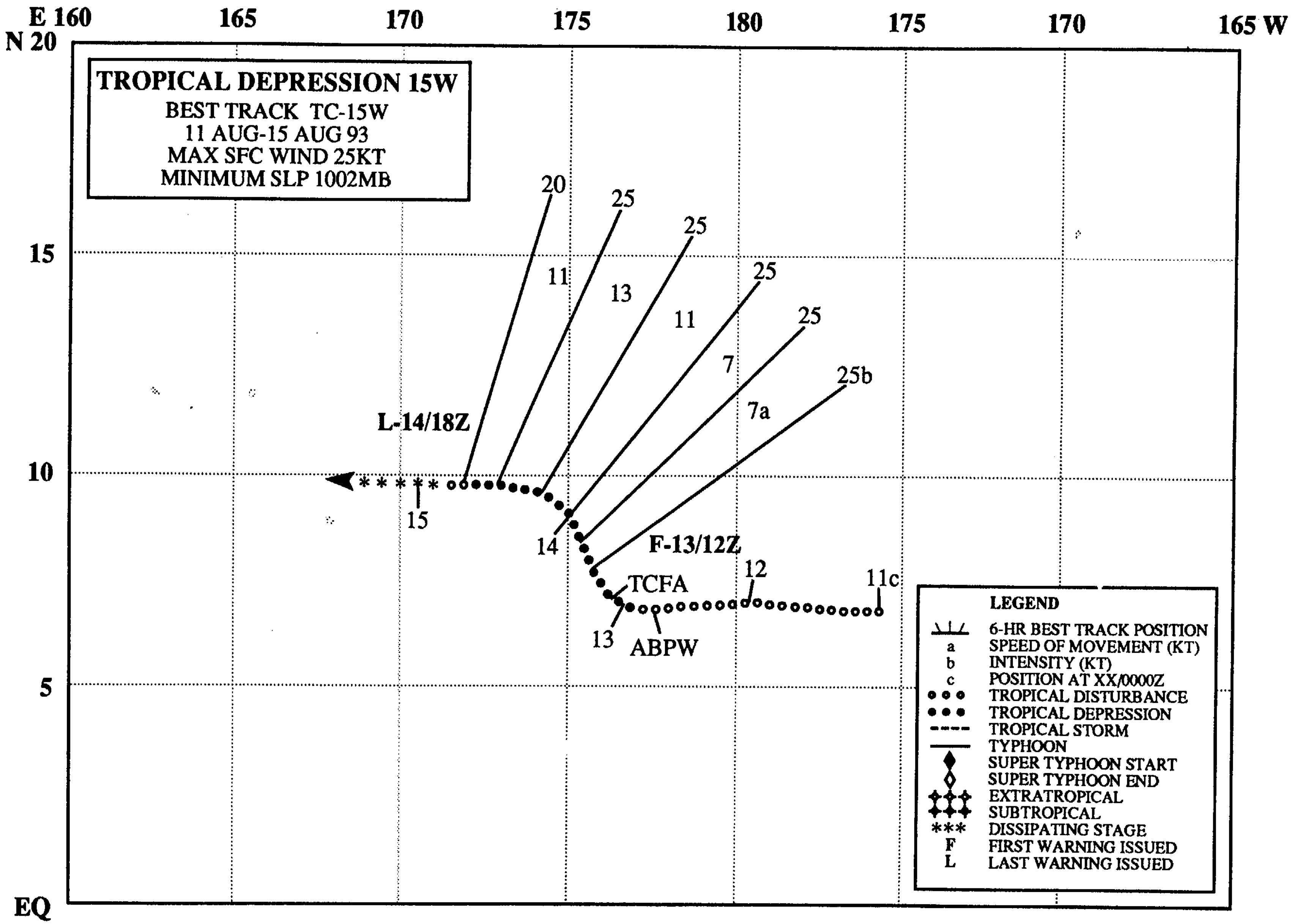


Figure 3-14-3 Illustration depicting the size and shape of Steve's cirrus canopy from 5 to 13 August: (a) unidirectional westerly winds aloft, (b) highly diffluent west winds aloft, and (c) unidirectional easterly winds aloft. Black areas = dense cirrus overcast and dashed lines = the extent of thin cirrus.



TROPICAL DEPRESSION 15W
BEST TRACK TC-15W
11 AUG-15 AUG 93
MAX SFC WIND 25KT
MINIMUM SLP 1002MB
E 160
165
170
175
180
175
170
165 W
N 20
15
10
5
EQ
L-14/18Z
F-13/12Z
TCFA
ABPW
20
25
25
25
25
25b
11
13
11
7
7a
15
14
13
12
11c
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TROPICAL DEPRESSION 15W

I. HIGHLIGHTS

Forming near the international date line, Tropical Depression 15W was hindered by persistent upper-level wind shear resulting in a short-lived system which, like Tropical Depression 01W earlier, required only five warnings (Figure 3-15-1).

II. CHRONOLOGY OF EVENTS

August

121800Z - When the convection associated with the disturbance increased, the Significant Tropical Weather Advisory was reissued to include the disturbance as a fair suspect area.

130300Z - A Tropical Cyclone Formation Alert was issued following an increase in convective organization.

131200Z - Based on a satellite intensity estimate of 25 kt (13 m/sec), JTWC issued the first warning.

141800Z - The final warning was issued as the depression dissipated due to persistent upper level shear which left behind an exposed low-level circulation.

III. IMPACT

None.

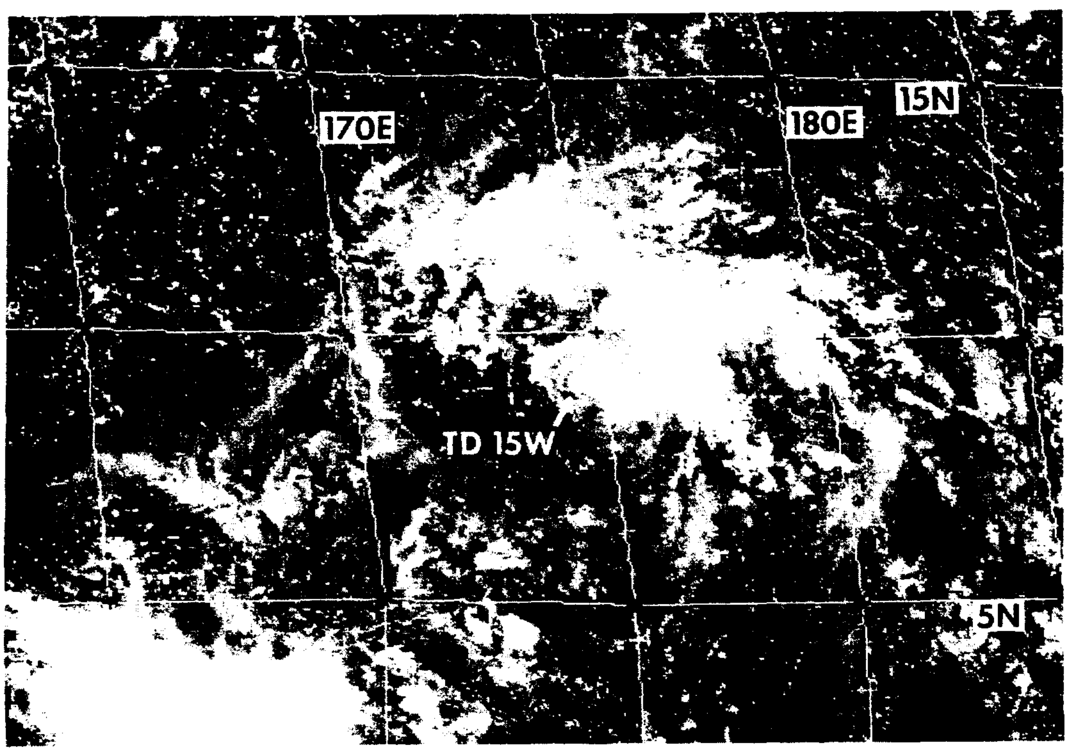
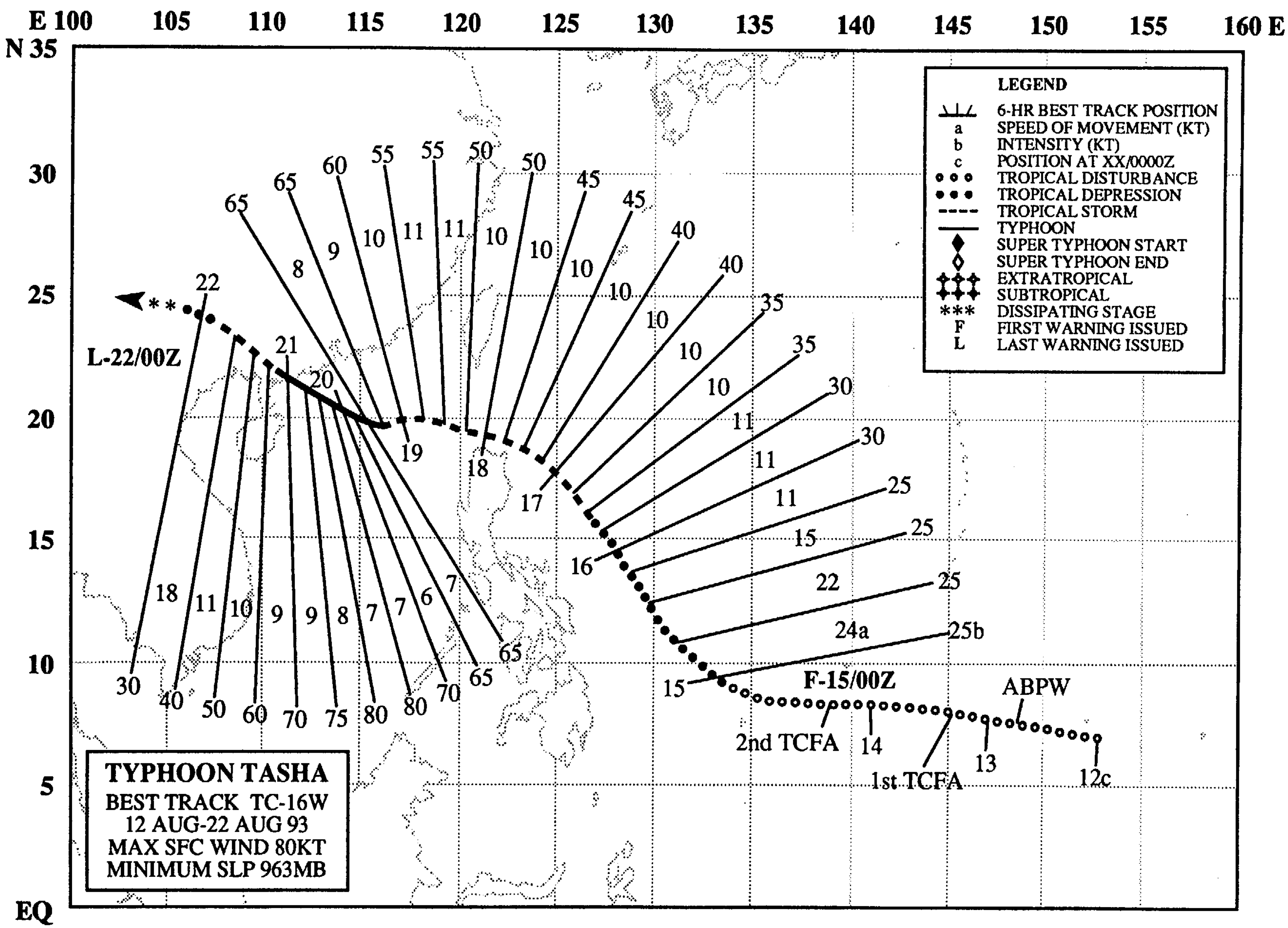


Figure 3-15-1 Convection associated with TD 15W is persistent, but remains poorly organized (140231Z August visual GMS imagery).


TYPHOON TASHA
BEST TRACK TC-16W
12 AUG-22 AUG 93
MAX SFC WIND 80KT
MINIMUM SLP 963MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-22/00Z
F-15/00Z
ABPW
1st TCFA
2nd TCFA
12c
24a
25b
E 100
105
110
115
120
125
130
135
140
145
150
155
160 E
N 35
30
25
20
15
10
5
EQ

TYPHOON TASHA (16W)

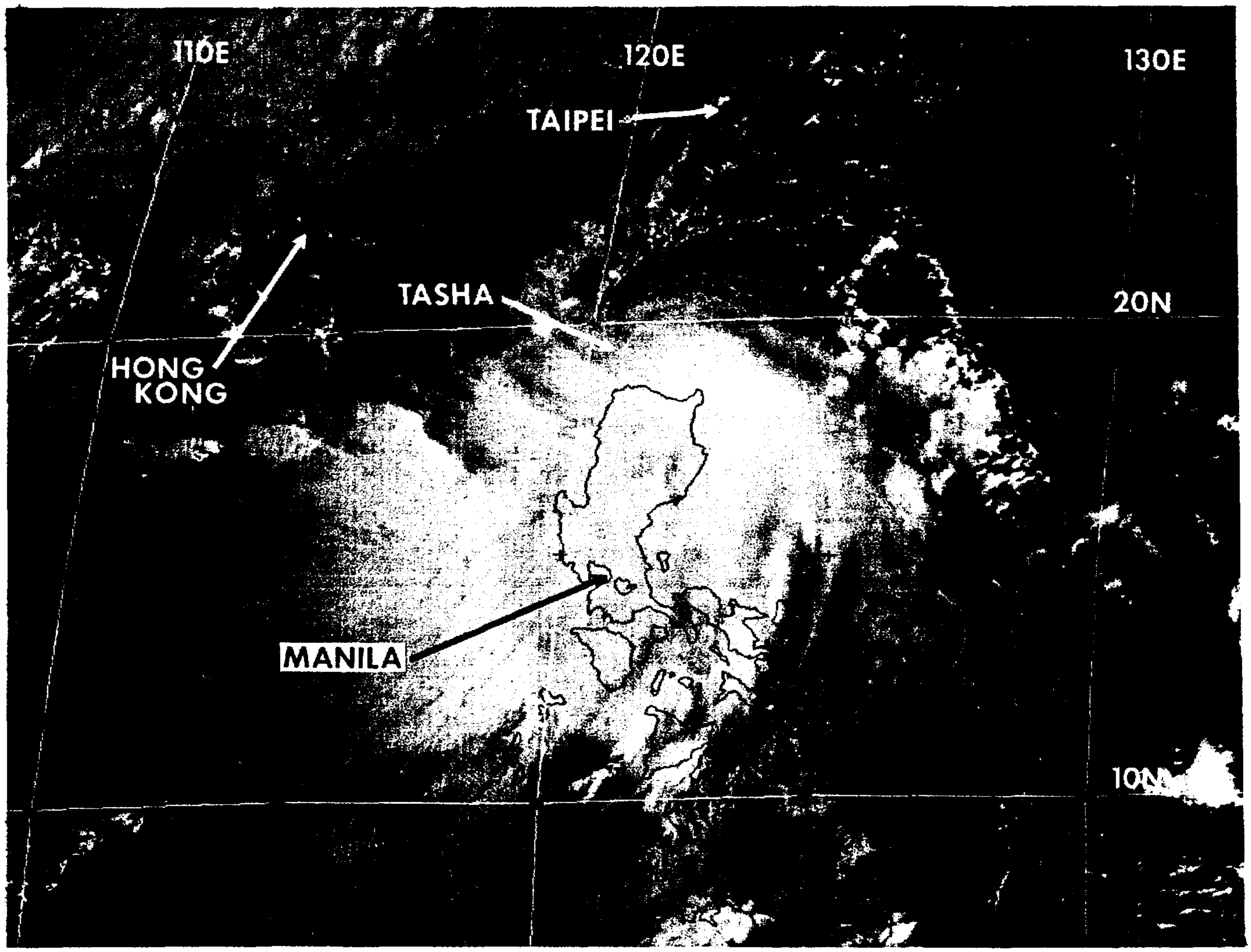


Figure 3-16-1 As Tasha passes north of Manila, bands of deep convection cover the island of Luzon (172331Z August visual GMS imagery.)

I. HIGHLIGHTS

Forming within the monsoon trough near Chuuk in the central Caroline Islands, Tasha was the fourth significant tropical cyclone of August. Tasha intensified slowly, but steadily, as it tracked northwestward across the Philippine Sea and into the South China Sea where it briefly threatened Hong Kong.

II. CHRONOLOGY OF EVENTS

August

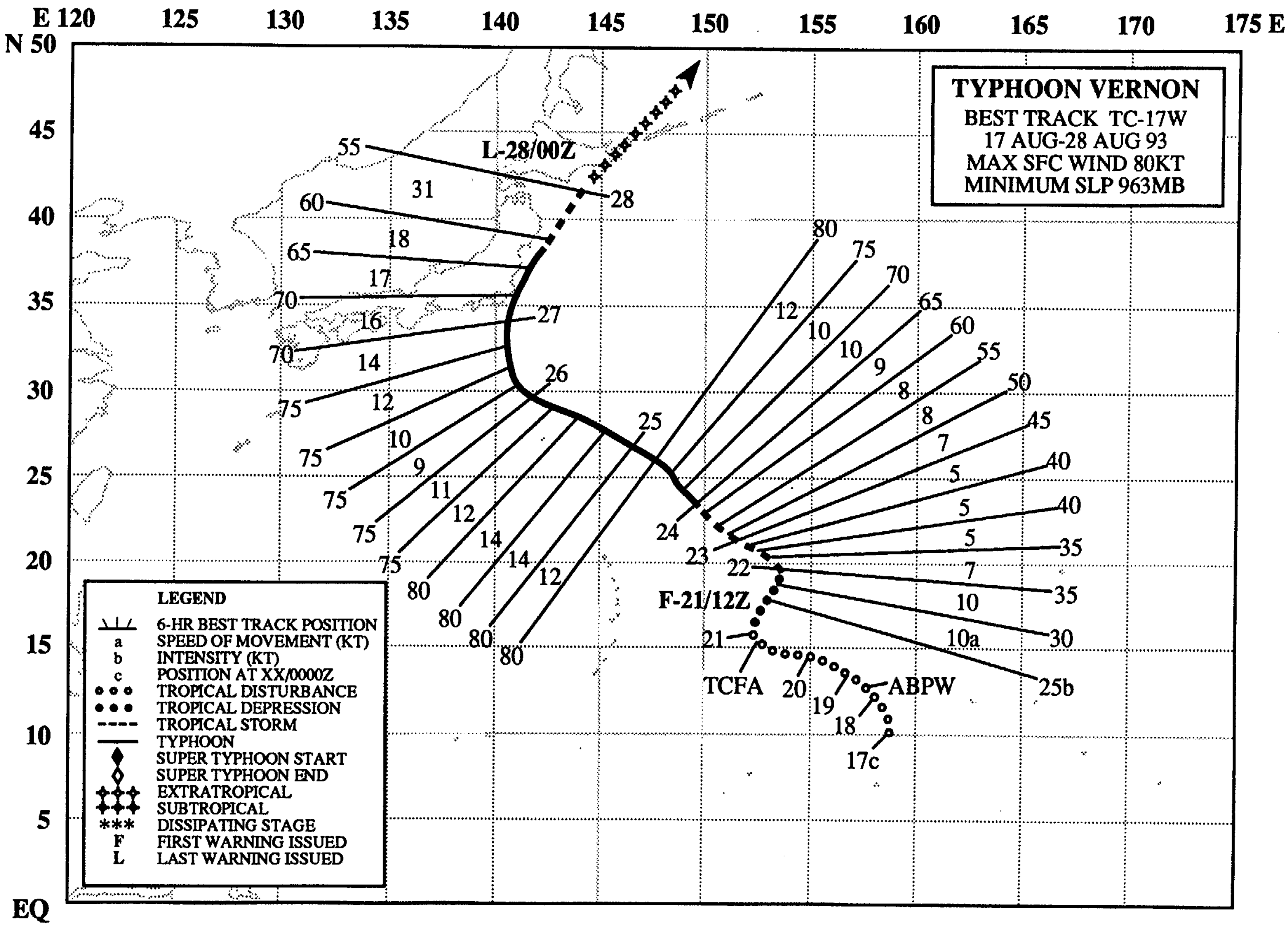
121800Z - The disturbance was first mentioned in the Significant Tropical Weather Advisory as an area of persistent convection embedded within the monsoon trough.

130800Z - The first Tropical Cyclone Formation Alert (TCFA) was issued based on an increase in convection.

140800Z - While the disturbance did not intensify significantly during the first TCFA, conditions remained favorable for development, and a second TCFA was issued.
150000Z - The first warning was issued based on gradient-level winds of 31 kt (16 m/sec) at Koror (WMO 91408).
161200Z - Based upon increased convective curvature and a satellite intensity estimate of 35 kt (18 m/sec), Tasha was upgraded to a tropical storm.
190600Z - Following a satellite intensity estimate of 65 kt (33 m/sec) which also indicated that upper-level shear had abated, Tasha was upgraded to a typhoon.
220000Z - The final warning was issued as the tropical cyclone dissipating over land in southern China.

III. IMPACT

Flooding from heavy rains associated with Tasha (Figure 3-16-1) as it passed north of Luzon, forced 21,000 people to evacuate homes in low-lying areas in Manila.


TYPHOON VERNON
BEST TRACK TC-17W
17 AUG-28 AUG 93
MAX SFC WIND 80KT
MINIMUM SLP 963MB
E 120
125
130
135
140
145
150
155
160
165
170
175 E
N 50
45
40
35
30
25
20
15
10
5
EQ
L-28/00Z
F-21/12Z
TCFA
ABPW
17c
25b
10a
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON VERNON (17W)

I. HIGHLIGHTS

Vernon formed east of the Mariana Islands as Typhoon Keoni (01C) was moving over open water to the northeast and Typhoon Tasha (16W) was moving inland over China. Threatening Japan, Vernon passed to the east of Tokyo as it skirted the east coast of Honshu. Vernon continued towards the north-northeast where it slowly weakened and eventually transitioned into an extratropical low in the Sea of Okhotsk.

II.CHRONOLOGY OF EVENTS

August

180600Z - Vernon was first mentioned in the Significant Tropical Weather Advisory as an extensive area of convection within the monsoon trough north of Pohnpei.

201700Z - Increased convection, associated with the disturbance, led to the issuance of a Tropical Cyclone Formation Alert.

211200Z - The first warning was issued based on increased convective curvature and a satellite intensity estimate of 25 kt (13 m/sec).

220000Z - Vernon was upgraded to tropical storm intensity following a satellite estimate of 35 kt (18 m/sec).

240000Z - A satellite intensity estimate of 65 kt (33 m/sec) was the impetus for upgrading Vernon to a typhoon (Figure 3-17-1).

280000Z - The final warning was issued as Vernon transitioned into an extratropical low in the Sea of Okhotsk.

III. IMPACT

Japanese news agencies reported two deaths and four injuries. More than 7800 homes and businesses were flooded. There were also numerous landslides, and washed out bridges, roads, and railways. The Naval Meteorology and Oceanography Command Facility at Yokosuka reported maximum sustained winds of 45 kt gusting to 62 kt (23G32 m/sec). Further from Vernon's track and inland, the Naval Meteorology and Oceanography Command Detachment at Atsugi observed maximum sustained winds of 35 kt gusting to 49 kt (18G25 m/sec).

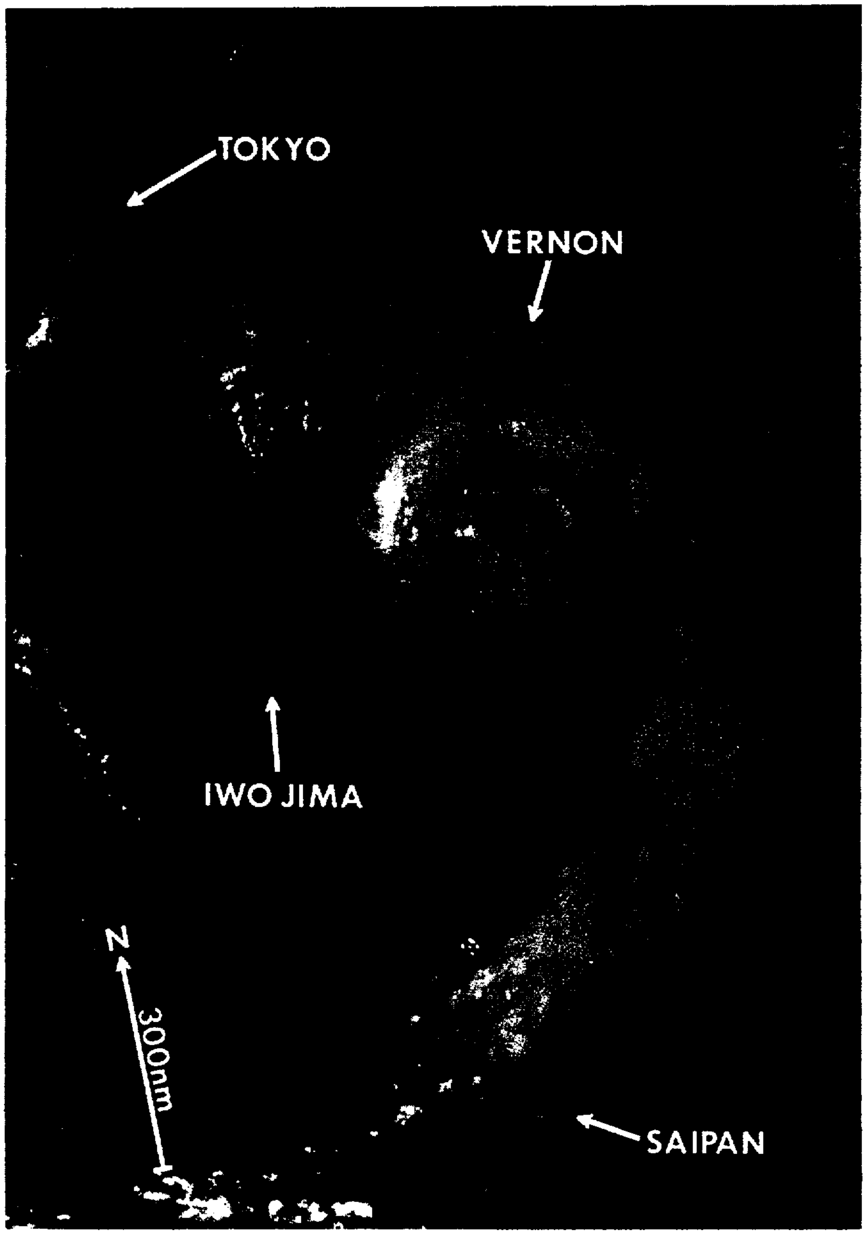
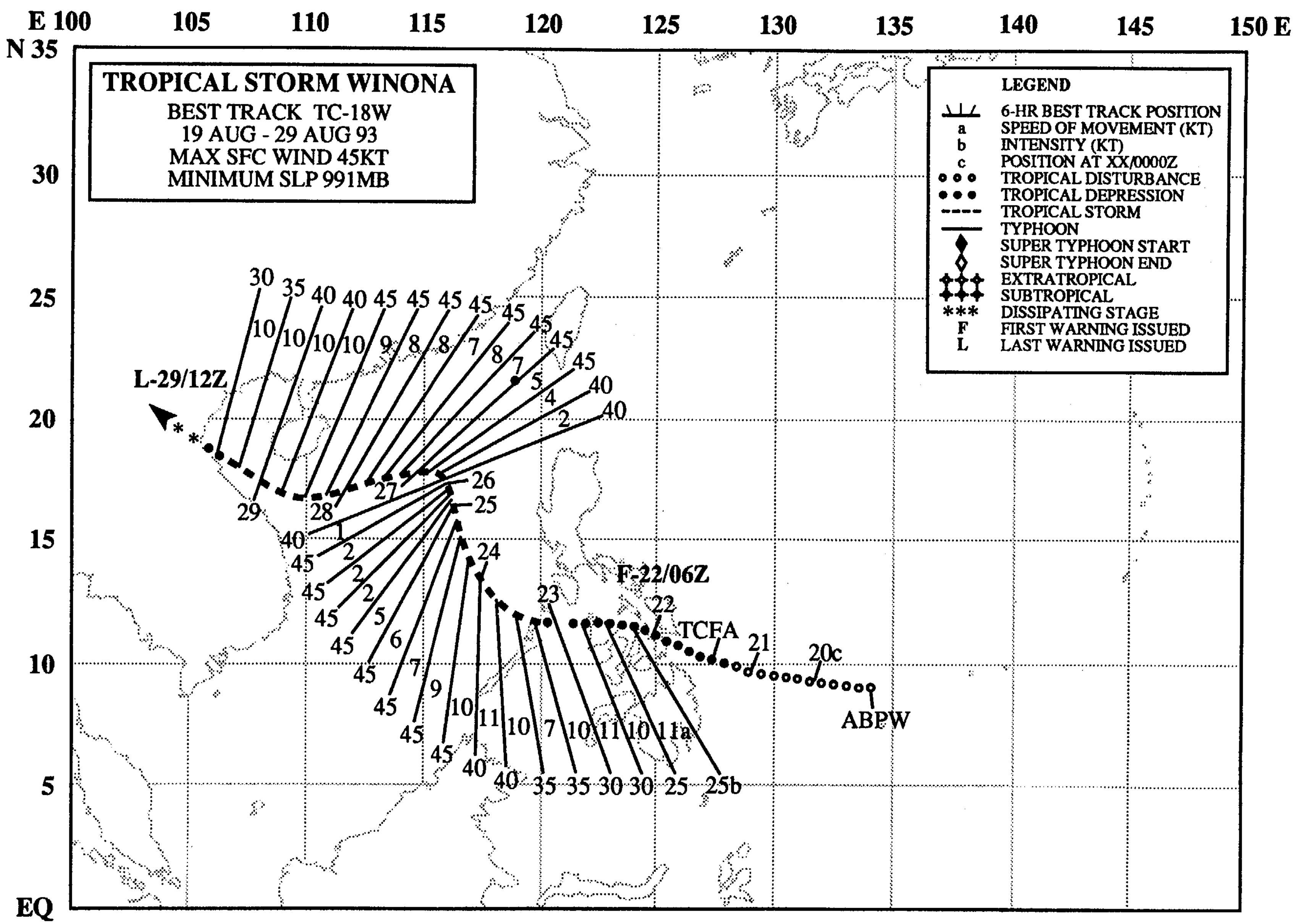


Figure 3-17-1 Typhoon Vernon, a day after reaching its peak intensity, heads toward Tokyo. Part of Keoni's (01C) cloud shield appears in the top right corner of the picture (250021Z August visual DMSP imagery).


TROPICAL STORM WINONA
BEST TRACK TC-18W
19 AUG - 29 AUG 93
MAX SFC WIND 45KT
MINIMUM SLP 991MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-29/12Z
F-22/06Z
TCFA
ABPW
E 100
105
110
115
120
125
130
135
140
145
150 E
N 35
30
25
20
15
10
5
EQ

TROPICAL STORM WINONA (18W)

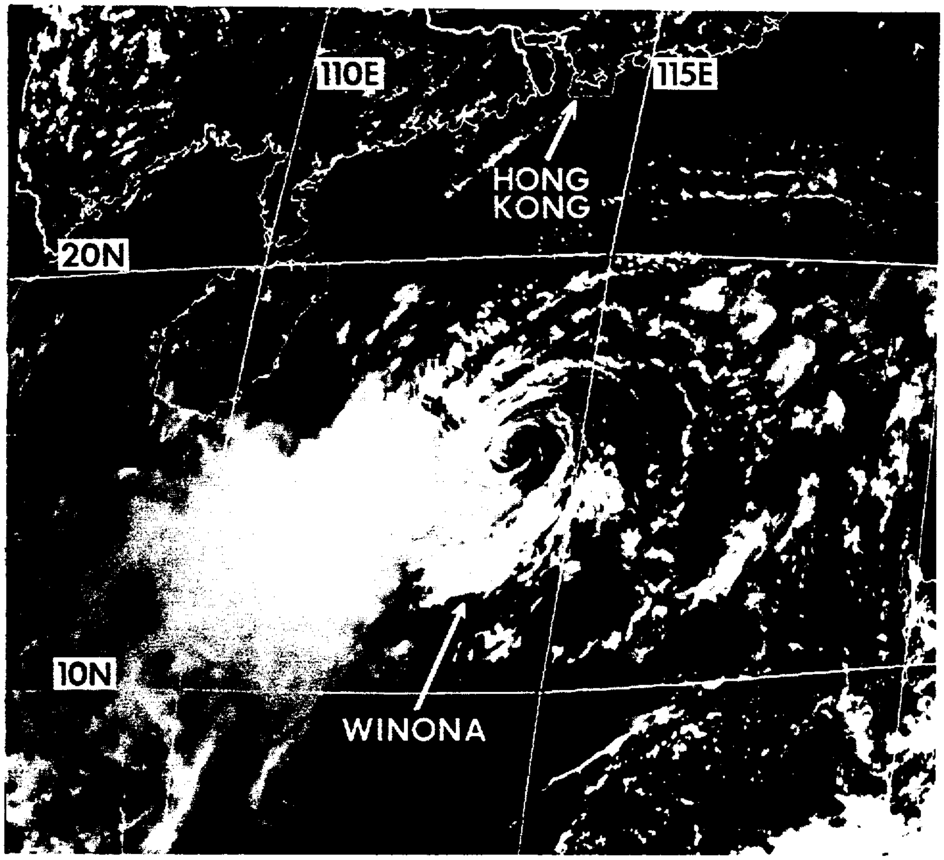


Figure 3-18-1 Convection displaced to the southwest, by strong upper tropospheric winds, fully exposes the low-level circulation center of Tropical Storm Winona (242330Z August visual GMS imagery).

I. HIGHLIGHTS

Initially forming west of Palau in the Philippine Sea, Winona slowly intensified while crossing the central Philippine Islands. Upon entering the South China Sea, Winona continued to slowly intensify, but reached an intensity plateau of 40 to 45 kt (20 to 23 m/sec) that lasted for four days. Increasing upper tropospheric wind shear weakened the storm as it moved westward (Figure 3-18-1). Winona ultimately moved over Vietnam and dissipated.

II. CHRONOLOGY OF EVENTS

August

190600Z - Persistent convection within the monsoon trough, near the western Caroline Islands, resulted in the first discussion of the disturbance in the Significant Tropical Weather Advisory.

211200Z - A Tropical Cyclone Formation Alert was issued following an increase in convective organization.

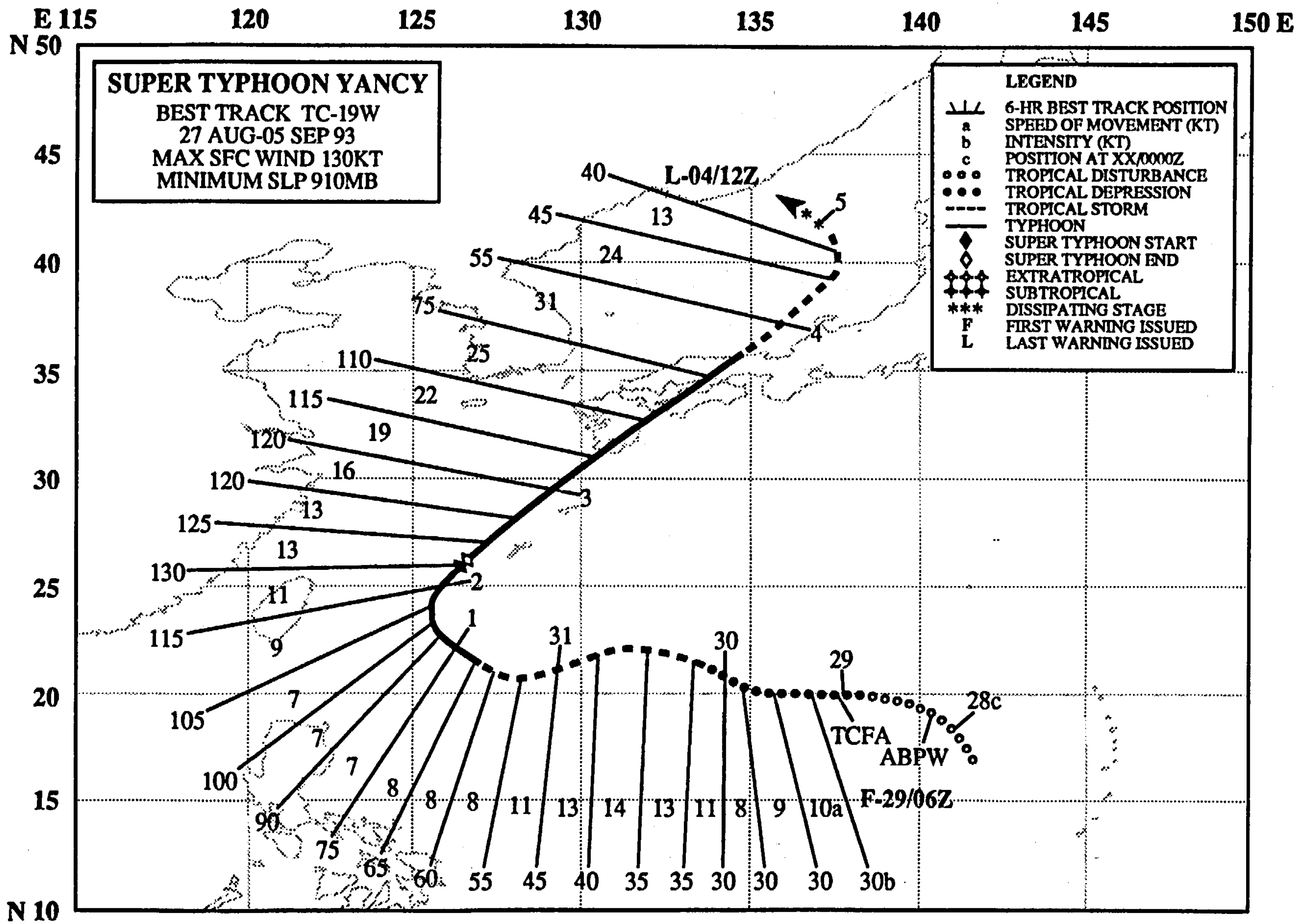
220600Z - The first warning was issued based on increased convective curvature and a satellite intensity estimate of 25 kt (13 m/sec).

230600Z - Following a satellite intensity estimate of 35 kt (18 m/sec),
Winona was upgraded to tropical storm intensity.

291200Z - The final warning was issued on Winona as it dissipated over Vietnam.

III. IMPACT

No reports were received.



SUPER TYPHOON YANCY
BEST TRACK TC-19W
27 AUG-05 SEP 93
MAX SFC WIND 130KT
MINIMUM SLP 910MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 115
120
125
130
135
140
145
150 E
N 50
45
40
35
30
25
20
15
N 10
L-04/12Z
F-29/06Z
TCFA
ABPW
28c
10a
30b

SUPER TYPHOON YANCY (19W)

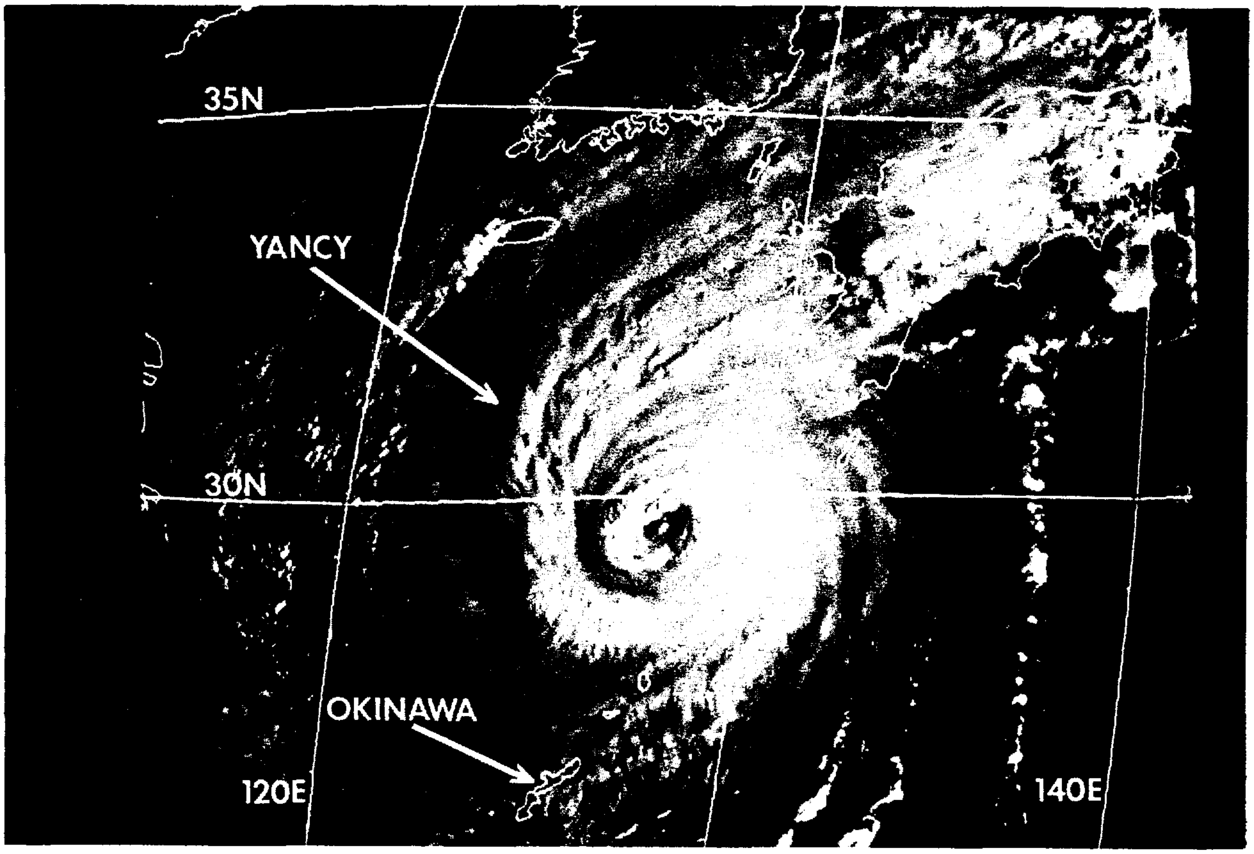


Figure 3-19-1 Visual image of Super Typhoon Yancy with a large, elongated eye, approximately seven hours prior to landfall in southern Kyushu. At this time, Yancy's maximum sustained winds were estimated to be 120 kt (62 m/sec) (022330Z September visual GMS imagery.)

I. HIGHLIGHTS

Striking southern Kyushu with sustained winds of 115 kt (60 m/sec), Yancy was one of the most powerful typhoons to hit Japan in decades (Figure 3-19-1). Forming in the Philippine Sea, Yancy tracked westward toward Taiwan, until it reached typhoon intensity. The tropical cylone then turned to the northeast and rapidly intensified into a super typhoon, passing within 60 nm (110 km) of Okinawa. Yancy was the second of three super typhoons of the 1993 tropical cyclone season.

II. CHRONOLOGY OF EVENTS

August

280600Z - An area of persistent convection generated by convergent southwesterly monsoonal flow resulted in the first discussion of the disturbance in the Significant Tropical Weather Advisory.

290100Z - A Tropical Cyclone Formation Alert was issued on the disturbance when convection consolidated near the circulation center.

290600Z - The first warning was issued based on a satellite intensity estimate of 25 kt (13 m/sec).

300600Z - Based on a ship report of 40 kt (21 m/sec) 60 nm (110 km) east of the system center, Yancy was upgraded to tropical storm intensity.

311800Z - Following the development of a well developed banding eye feature and a satellite intensity estimate of 65 kt (33 m/sec), Yancy was upgraded to typhoon intensity.

September

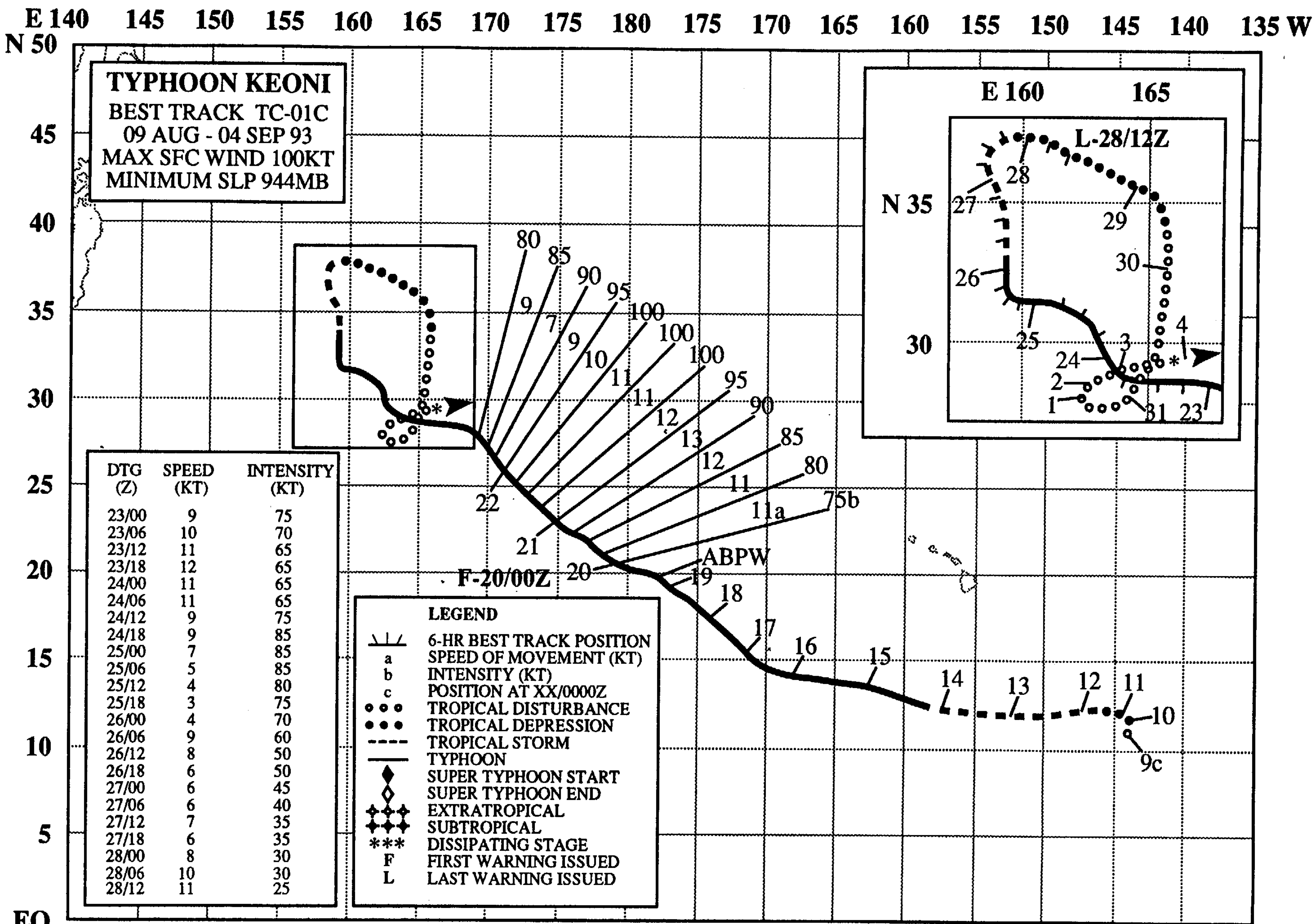
020600Z - After a period of rapid intensification and a subsequent satellite intensity estimate of 127 kt (65 m/sec), Yancy was upgraded to super typhoon intensity.

041200Z - The final warning was issued as Yancy dissipated in the Sea of Japan.

III. IMPACT

Making landfall over southern Kyushu at approximately 030700Z, Yancy packed estimated maximum sustained winds of 115 kt (59 m/sec). Weather observations from Kanoya, Japan (WMO 47850), along coastal southern Kyushu, reported maximum gusts of 129 kt (66 m/sec). A total of 42 deaths (27 in Kagoshima Prefecture near the point of landfall), 155 injuries, and 5 missing people were attributed to Yancy as it traversed over Japan. More than 124 homes were destroyed, 4620 homes and businesses damaged, and 400,000 homes were without electricity. In addition, there was extensive agricultural damage and a widespread disruption of rail and airline travel in Southeastern Honshu.

Maximum winds at Kadena AB, Okinawa were reported at 48 kt with gusts to 77 kt (25G40 m/sec). Sasebo and Iwakuni reported weaker maximum sustained winds of 28 kt gusting to 56 kt (14G29 m/sec) and 30 kt gusting to 45 (15G23 m/sec), respectively.



DTG (Z)	SPEED (KT)	INTENSITY (KT)
23/00	9	75
23/06	10	70
23/12	11	65
23/18	12	65
24/00	11	65
24/06	11	65
24/12	9	75
24/18	9	85
25/00	7	85
25/06	5	85
25/12	4	80
25/18	3	75
26/00	4	70
26/06	9	60
26/12	8	50
26/18	6	50
27/00	6	45
27/06	6	40
27/12	7	35
27/18	6	35
28/00	8	30
28/06	10	30
28/12	11	25

TYPHOON KEONI (01C)

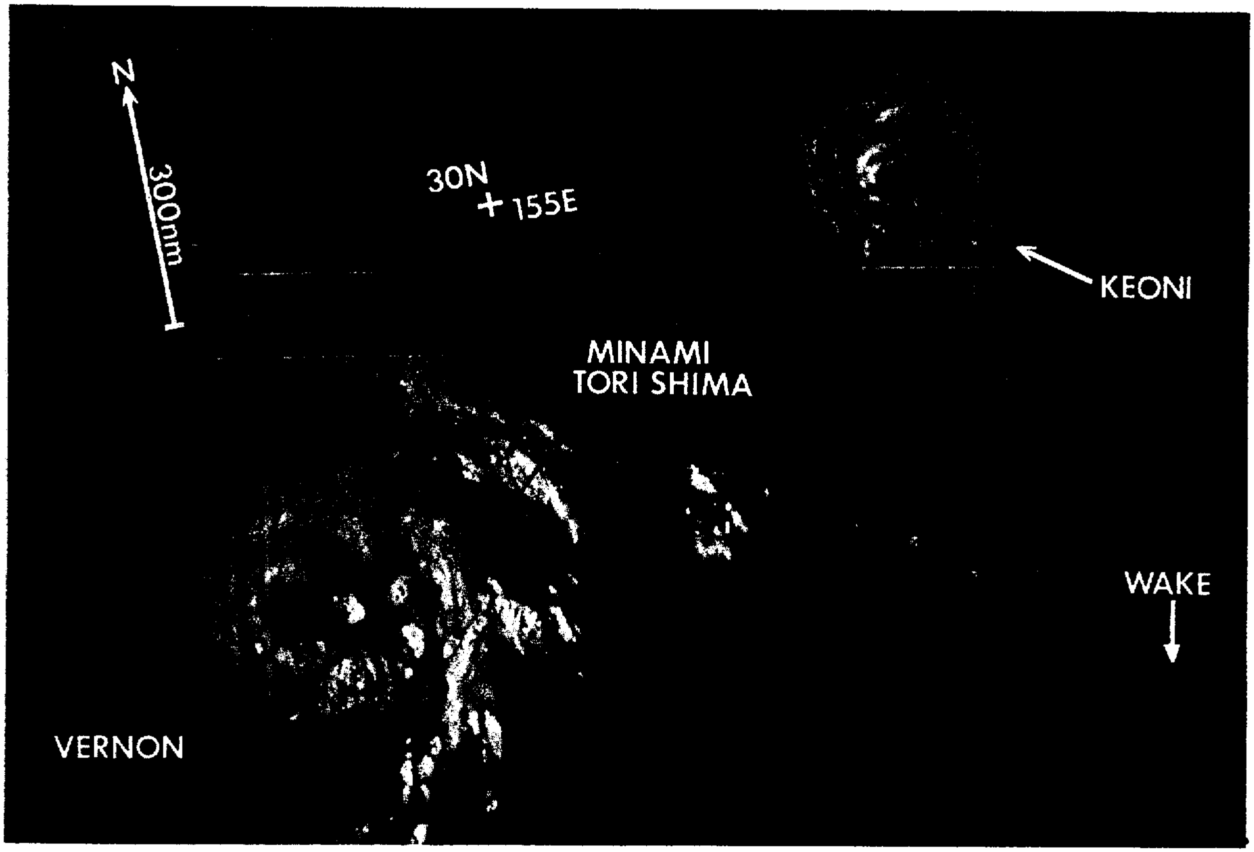


Figure 3-01C-1 Keoni tracks in tandem with Vernon (17W) (242313Z August visual NOAA imagery.)

I. HIGHLIGHTS

Typhoon Keoni formed southeast of Hawaii in the central Pacific and crossed into the JTWC area of responsibility on 20 August. Keoni remained over open water its entire life and did not pose a significant threat to land. Keoni tracked northwest in tandem with Typhoon Vernon (17W) before dissipating (Figure 3-01C-1) over cool water.

II. CHRONOLOGY OF EVENTS

August

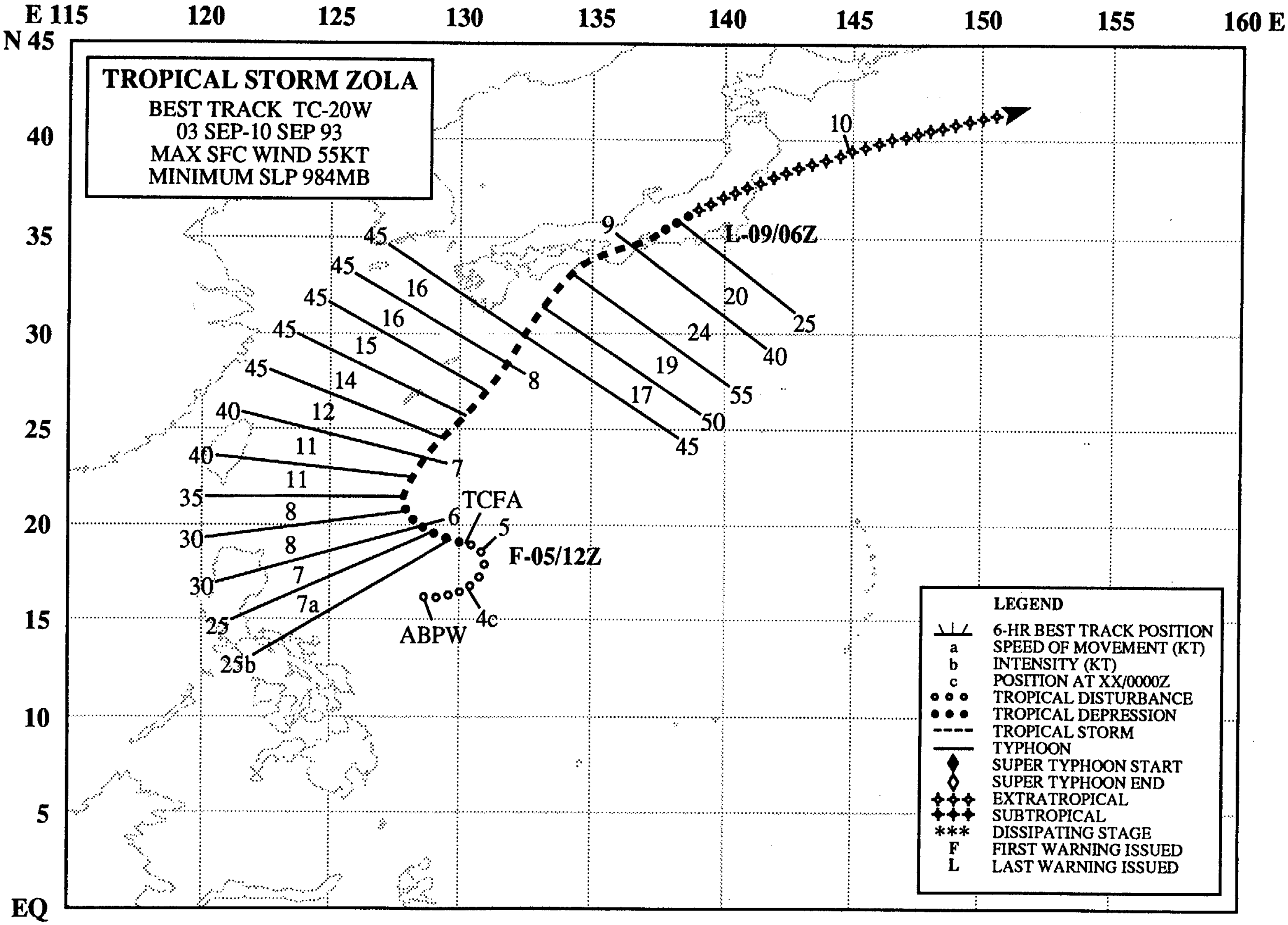
200000Z - The first warning on Typhoon Keoni is issued after the storm crossed the international date line into the JTWC area of responsibility.

210600Z - Keoni attained a maximum intensity of 100 kt (51 m/sec). Keoni earlier attained this maximum in the central Pacific.

281200Z - The final warning was issued on Keoni as it dissipated over cool water in an area of strong upper level vertical wind shear.

III. IMPACT

None.


TROPICAL STORM ZOLA
BEST TRACK TC-20W
03 SEP-10 SEP 93
MAX SFC WIND 55KT
MINIMUM SLP 984MB
E 115
120
125
130
135
140
145
150
155
160 E
N 45
40
35
30
25
20
15
10
5
EQ
TCFA
F-05/12Z
ABPW
L-09/06Z
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TROPICAL STORM ZOLA (20W)

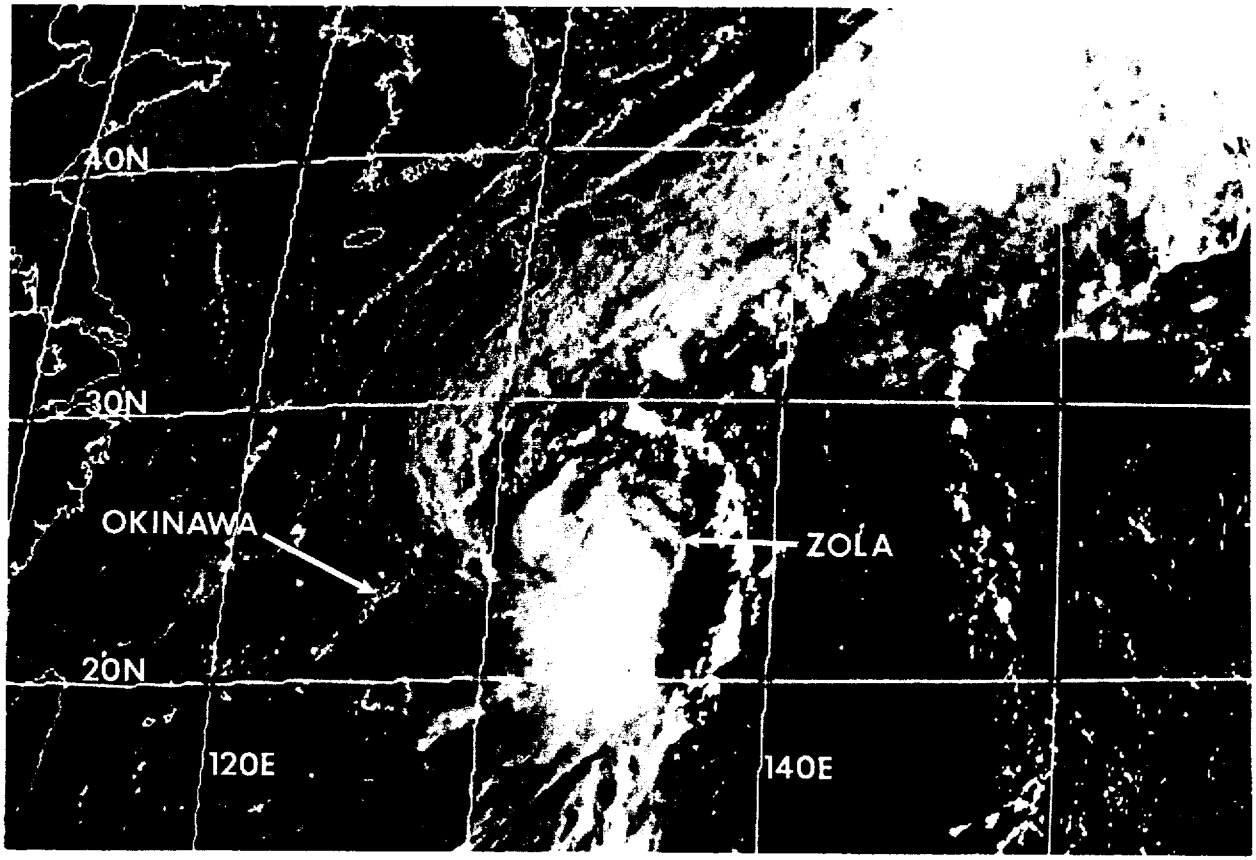


Figure 3-20-1 Zola at tropical storm intensity passes to the east of Okinawa (072230Z September visual GMS imagery).

I. HIGHLIGHTS

Forming within the monsoon trough in the Philippine Sea, Zola was the first of six significant tropical cyclones to occur during September. Steadily accelerating north-northeastward and passing east of Okinawa (Figure 3-20-1), Zola reached it's maximum intensity of 55 kt (28 m/sec) just prior to landfall in Japan.

II. CHRONOLOGY OF EVENTS

September

030600Z - An area of convection within the monsoon trough, east of Luzon, resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.

050800Z - Increased convective organization, southwest of a cyclonic cell in the Tropical Upper Tropospheric Trough (TUTT), led to the issuance of a Tropical Cyclone Formation Alert on the disturbance.

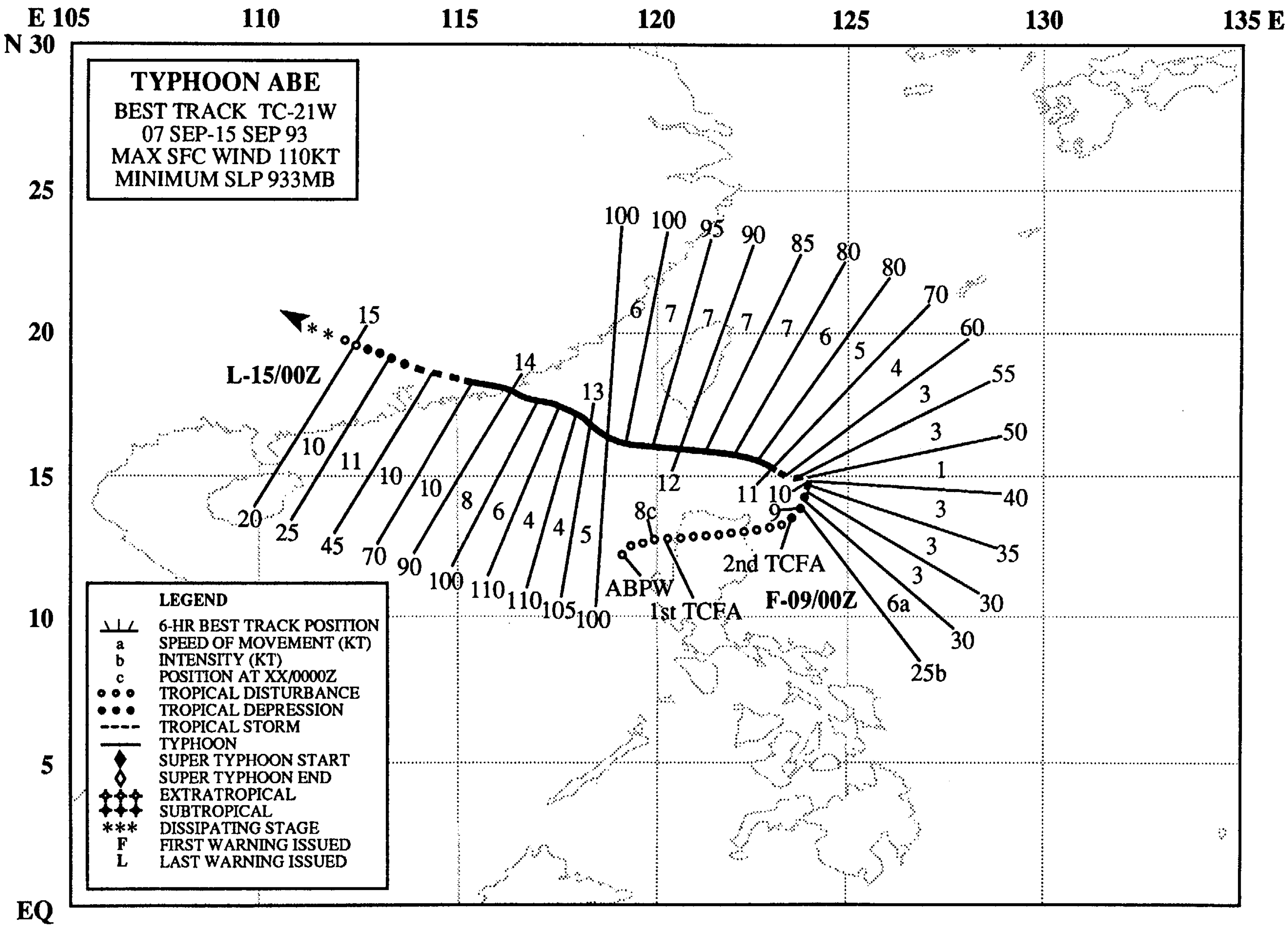
051200Z - The first warning was issued based on improved convective curvature and a satellite intensity estimate of 25 kt (13 m/sec).

061200Z - Based on a satellite intensity estimate of 35 kt (18 m/sec), Zola was upgraded to tropical storm intensity.

090600Z - The final warning was issued as Zola transitioned into an extratropical low over Honshu, Japan.

III. IMPACT

Press reports indicated that heavy rains associated with Zola flooded homes, caused landslides, and stopped train service in Wakayama, a Japanese prefecture 280 nm (520 km) southwest of Tokyo.



TYPHOON ABE
BEST TRACK TC-21W
07 SEP-15 SEP 93
MAX SFC WIND 110KT
MINIMUM SLP 933MB
E 105
110
115
120
125
130
135 E
N 30
25
20
15
10
5
EQ
L-15/00Z
F-09/00Z
ABPW
1st TCFA
2nd TCFA
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON ABE (21W)

I. HIGHLIGHTS

The first typhoon of September, Abe, initially took an unusual eastward track across Luzon, in the wake of Tropical Storm Zola (20W). After entering the Philippine Sea, Abe slowly turned back to the west, passed north of Luzon, and intensified to 110 kt (57 m/sec) before making landfall in China, east of Hong Kong. Radar images from Kaohsiung (WMO 46744) revealed a dramatic decrease in the diameter of the eye over a period of 20 hours (Figure 3-21-1) as Abe passed just to the south of Taiwan.

II. CHRONOLOGY OF EVENTS

September

070600Z - An area of persistent convection within the monsoon trough, west of Luzon, resulted in the first discussion of the disturbance in the Significant Tropical Weather Advisory.

080300Z - A Tropical Cyclone Formation Alert (TCFA) was issued on the disturbance in the South China Sea, following a period of rapid development in its convective organization.

082100Z - A second TCFA was issued after the disturbance crossed Luzon and reorganized in the Philippine Sea.

090000Z - The first warning was issued on the tropical depression following an improvement in convective curvature and a satellite intensity estimate of 25 kt (13 m/sec).

091800Z - Based on continuously increasing convective organization and a satellite intensity estimate of 35 kt (18 m/sec), Abe was upgraded to a tropical storm.

110000Z - Following the development of a cloud filled eye and a satellite intensity estimate of 77 kt (40 m/sec), Abe was upgraded to typhoon intensity.

150000Z - The final warning was issued on Abe as it dissipated in southern China.

III. IMPACT

No reports received.

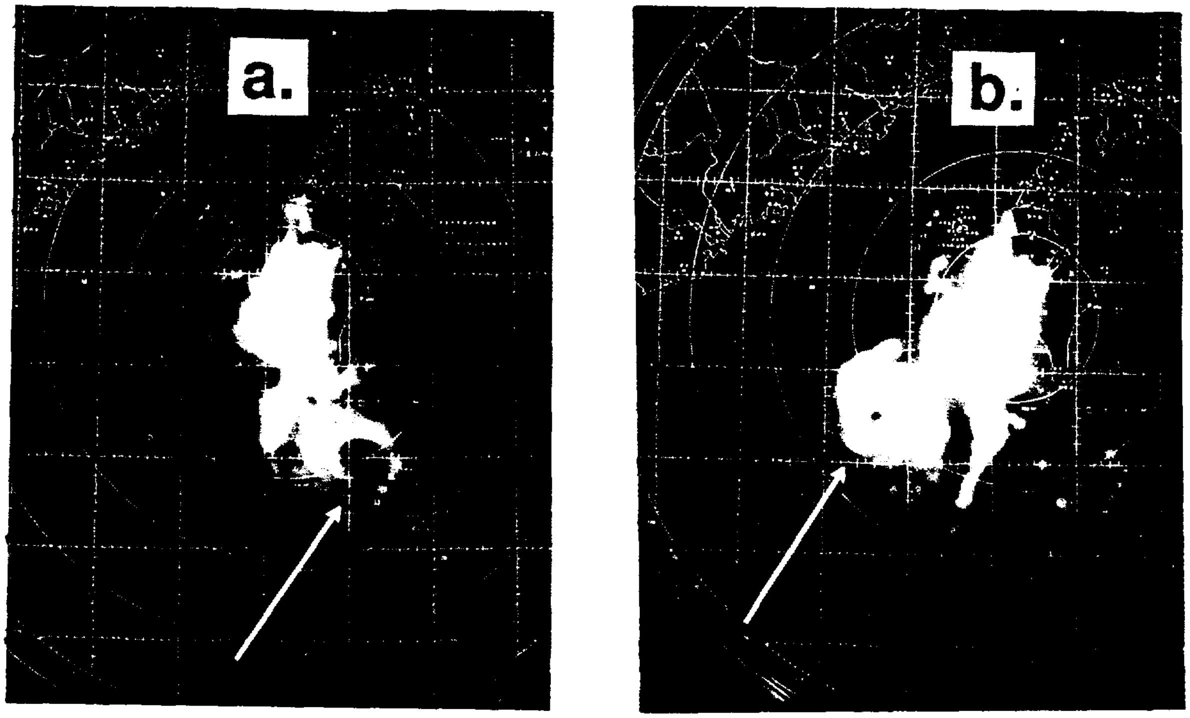
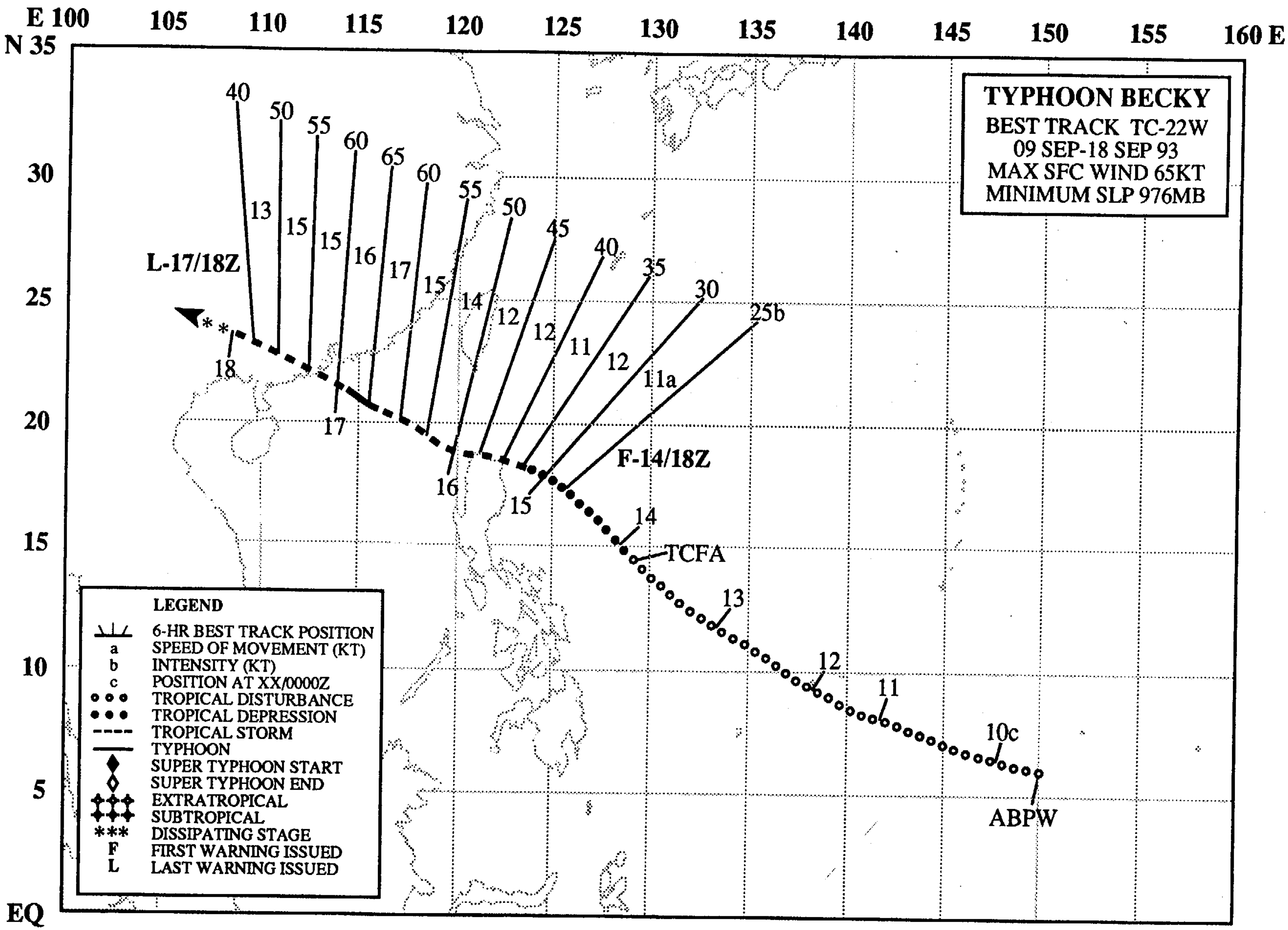


Figure 3-21-1 Radar images from Kaohsiung (WMO 46744): a) at 112200Z, and b) 121800Z September show the dramatic decrease in Abe's eye diameter from 25 to 8 nm (45 to 15 km) as intensification takes place (Radar photos courtesy of the Central Weather Bureau, Taipei, Taiwan).


TYPHOON BECKY
BEST TRACK TC-22W
09 SEP-18 SEP 93
MAX SFC WIND 65KT
MINIMUM SLP 976MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-17/18Z
F-14/18Z
TCFA
ABPW
10c
11
12
13
14
15
16
17
18
25b
11a
E 100
105
110
115
120
125
130
135
140
145
150
155
160 E
N 35
30
25
20
15
10
5
EQ

TYPHOON BECKY (22W)

I. HIGHLIGHTS

The third of six significant tropical cyclones to form during September, Becky remained a weak cyclonic disturbance while tracking towards northern Luzon. After the first warning was issued, Becky intensified at a faster than average rate and attained typhoon intensity 48 hours later. The tropical cyclone reached a peak intensity of 65 kt (33 m/sec) ten hours prior to landfall in southern China. Becky (Figure 3-22-1) was the second typhoon in three days to threaten Hong Kong.

II. CHRONOLOGY OF EVENTS

September

091800Z - An area of persistent convection within the monsoon trough, near the Caroline Islands, resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.

132000Z - A Tropical Cyclone Formation Alert was issued as a result of increased convection and convective curvature.

141800Z - The first warning was issued based on a satellite intensity estimate of 25 kt (13 m/sec).

150600Z - Based on satellite intensity estimates of 35 kt (18 m/sec), Becky was upgraded to a tropical storm, as it approached Luzon.

161800Z -With the development of a 13 nm (24 km) cloud-filled eye and a satellite intensity estimate of 65 kt (33 m/sec), Becky was briefly upgraded to typhoon intensity.

171800Z - The final warning was issued on Becky as it dissipated over southern China, southwest of Hong Kong.

III. IMPACT

Seven deaths and 60 people reported missing near Hong Kong were attributed to the passage of Becky.

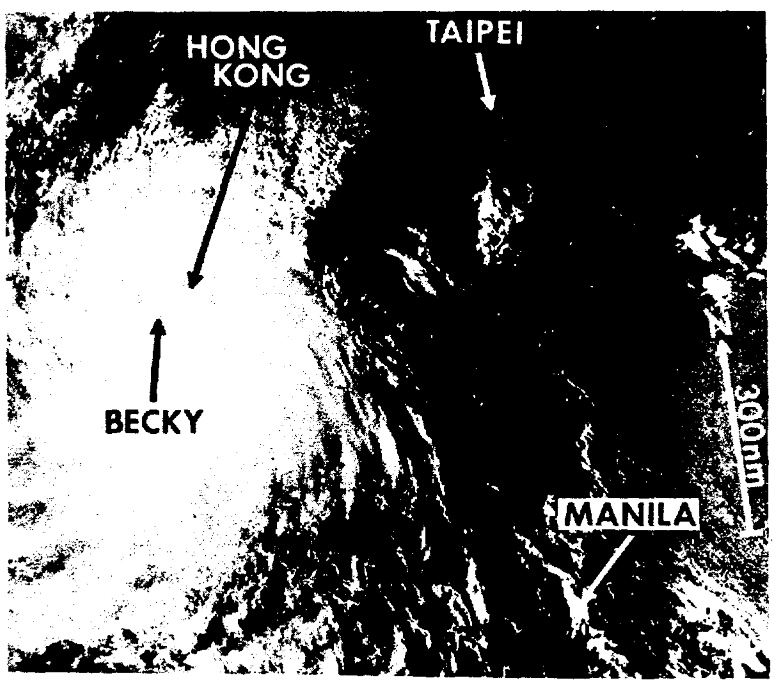
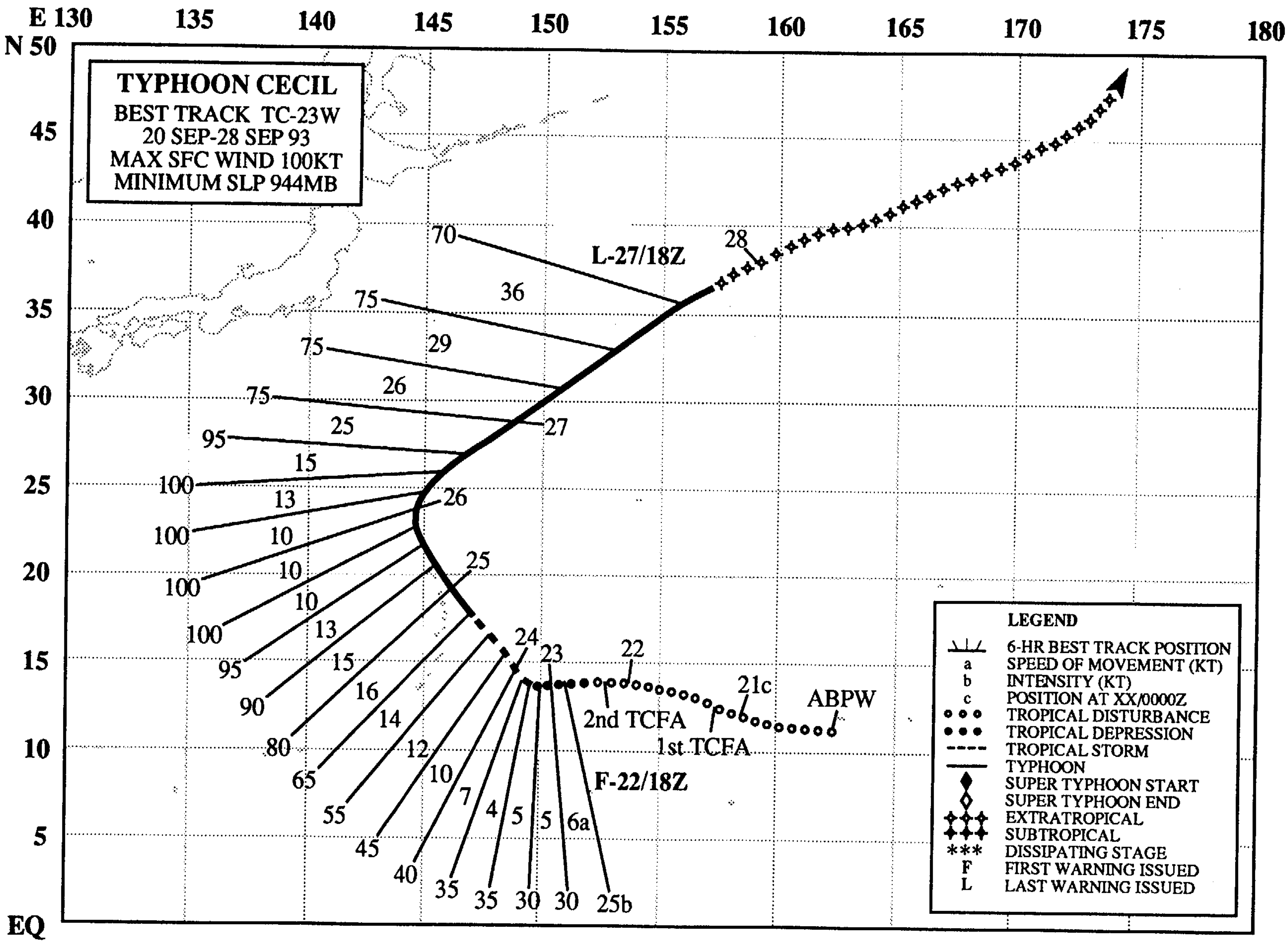


Figure 3-22-1 Typhoon Becky with a closed cloud filled eye makes land fall to the west of Hong Kong (170139Z September visual DMSP imagery.)


TYPHOON CECIL
BEST TRACK TC-23W
20 SEP-28 SEP 93
MAX SFC WIND 100KT
MINIMUM SLP 944MB
E 130
135
140
145
150
155
160
165
170
175
180
N 50
45
40
35
30
25
20
15
10
5
EQ
L-27/18Z
F-22/18Z
2nd TCFA
1st TCFA
ABPW
28
27
26
25
24
23
22
21c
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON CECIL (23W)

I. HIGHLIGHTS

The fourth significant tropical cyclone to develop during September, Cecil, briefly threatened the Mariana Islands before turning to the northwest and ultimately recurving away from any populated areas.

II. CHRONOLOGY OF EVENTS

September

200600Z - An area of persistent convection within an extended monsoon trough west of Kwajalein in the Marshall Islands resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.

210600Z - A Tropical Cyclone Formation Alert (TCFA) was issued based on an increase in convection and convective curvature.

220530Z - A further consolidation of convection near the circulation center and a westerly wind burst led to the issuance of a second TCFA.

221800Z - The first warning was issued based on a satellite intensity estimate of 25 kt (13 m/sec) while the depression was located east of Guam.

230000Z - As a result of continued development of convective curvature and a satellite intensity estimate of 35 kt (18 m/sec), Cecil was upgraded to tropical storm intensity. Post-storm analysis indicated that Cecil actually reached tropical storm intensity about twelve hours later.

241800Z - In response to a satellite intensity estimate of 65 kt (33 m/sec), Cecil was upgraded to typhoon intensity.

271800Z - The final warning was issued on Cecil as it transitioned into an extratropical low.

III. IMPACT

Convection associated with a monsoon surge flowing into Cecil brought badly needed rainfall to Guam as the water level in Guam's Fena Reservoir rose nearly 10 feet (3 m) (Figure 3-23-1).

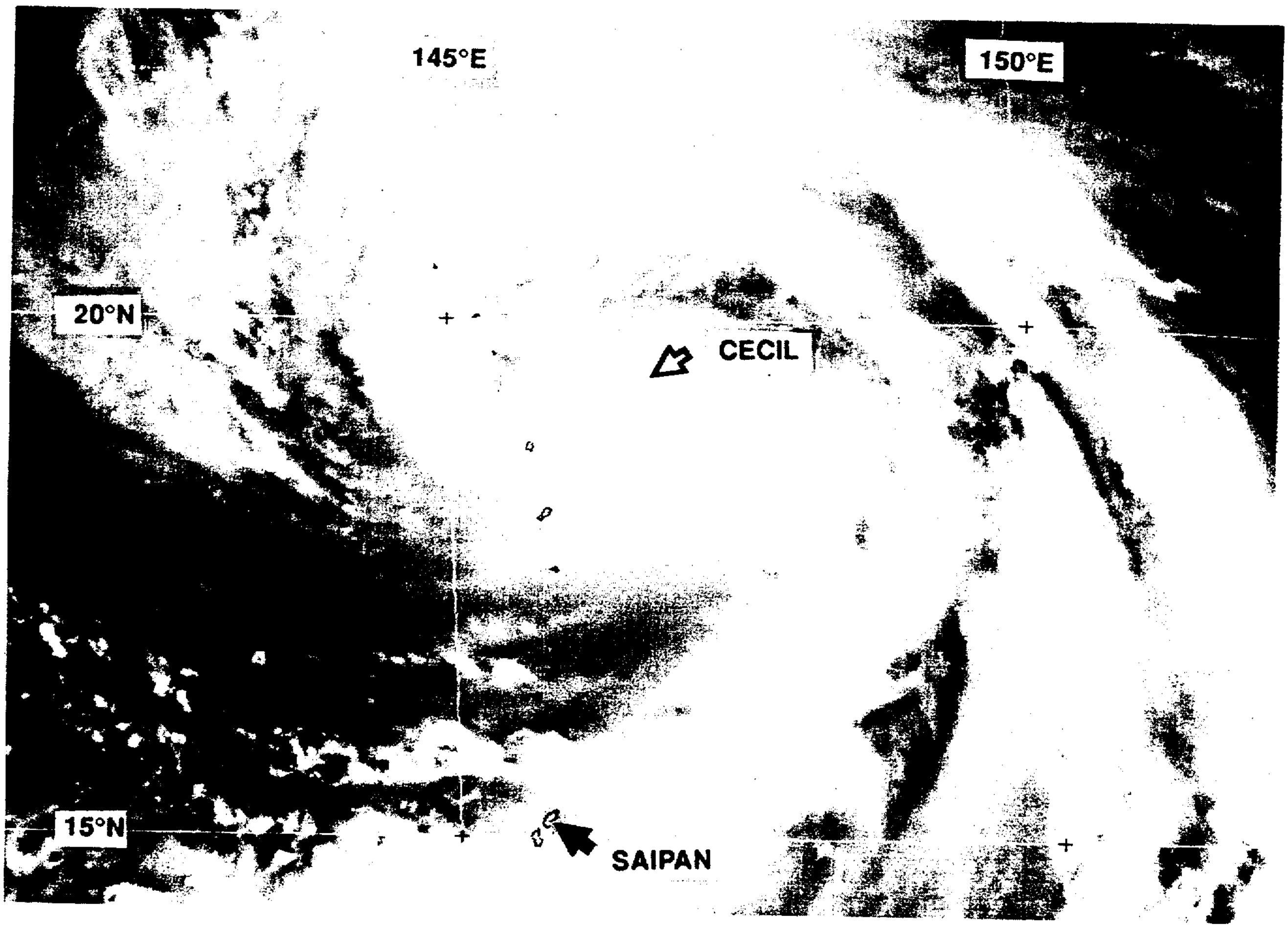
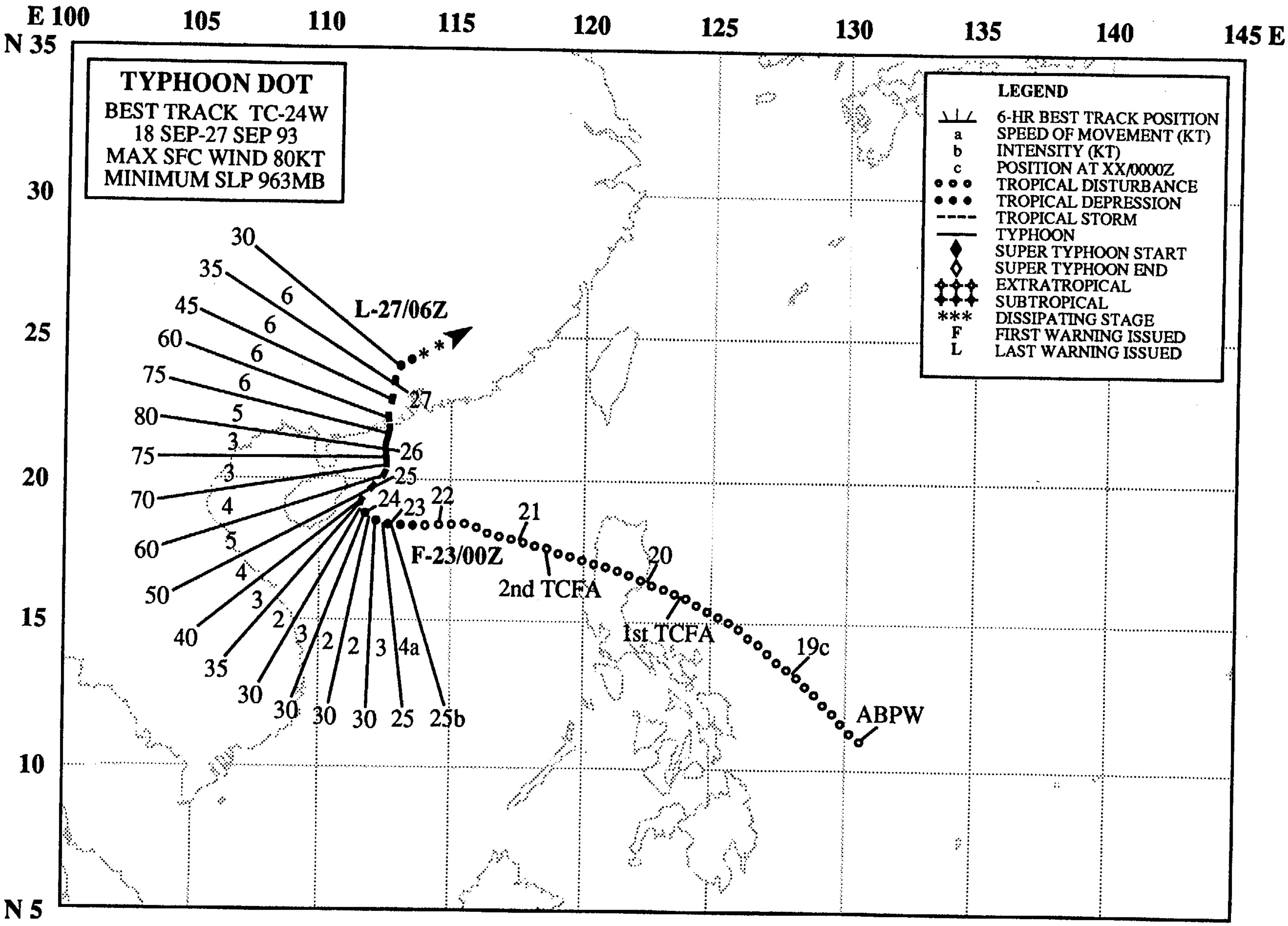


Figure 3-23-1 Although the cloud-filled eye of Typhoon Cecil is located 250 nm (465 km) to the north of Saipan, bands of deep convection are bringing heavy rains to the southern islands of the Marianas (242331Z September visual GMS imagery).


TYPHOON DOT
BEST TRACK TC-24W
18 SEP-27 SEP 93
MAX SFC WIND 80KT
MINIMUM SLP 963MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 100
105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
10
N 5
L-27/06Z
F-23/00Z
2nd TCFA
1st TCFA
ABPW
19c
20
21
22
23
24
25
26
27
4a
25b

TYPHOON DOT (24W)

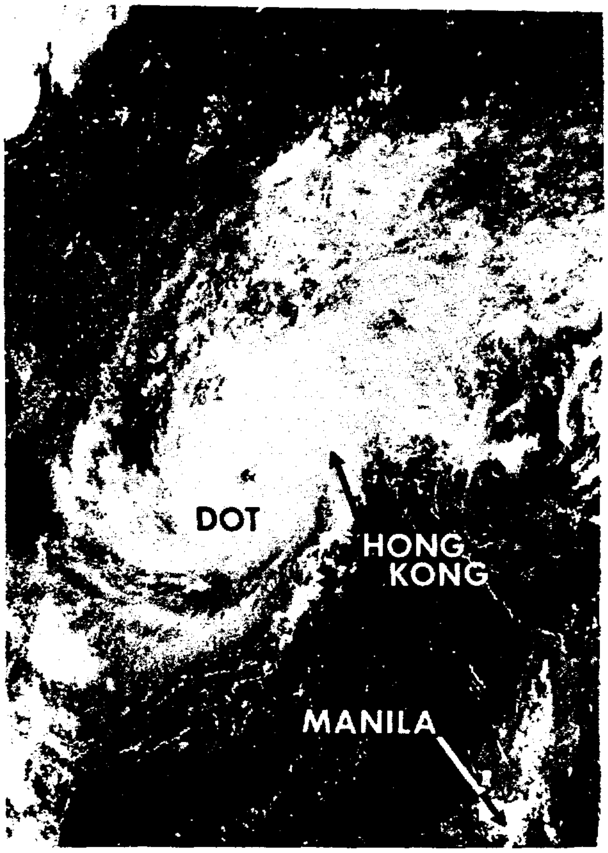


Figure 3-24-1 The eye of Dot, which is located southwest of Hong Kong, is visible in the moonlight. The city lights of Hanoi and Manila can also be seen (251321Z September nighttime visual DMSP imagery).

I. HIGHLIGHTS

Initially forming in the Philippine Sea, Dot slowly consolidated as it moved swiftly across Luzon. In the South China Sea, weak steering flow allowed Dot to slow to about 2 kt (1 m/sec), and intensify from a tropical depression to a typhoon. Moving erratically to the north, Dot eventually made landfall over southern China, near Hong Kong (Figure 3-24-1).

II. CHRONOLOGY OF EVENTS

September

180600Z - An area of persistent convection within the monsoon trough, north of Palau, resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.

191900Z - A Tropical Cyclone Formation Alert (TCFA) was issued following an increase in convection near the circulation center.

201900Z - A second TCFA was issued after the disturbance crossed Luzon with it's convective organization weakened but intact.

211900Z - The second TCFA was canceled due to decreased convective organization.

230000Z - The first warning was issued, without a TCFA in effect, based upon a synoptic report of 25 kt (13 m/sec) near the circulation center.

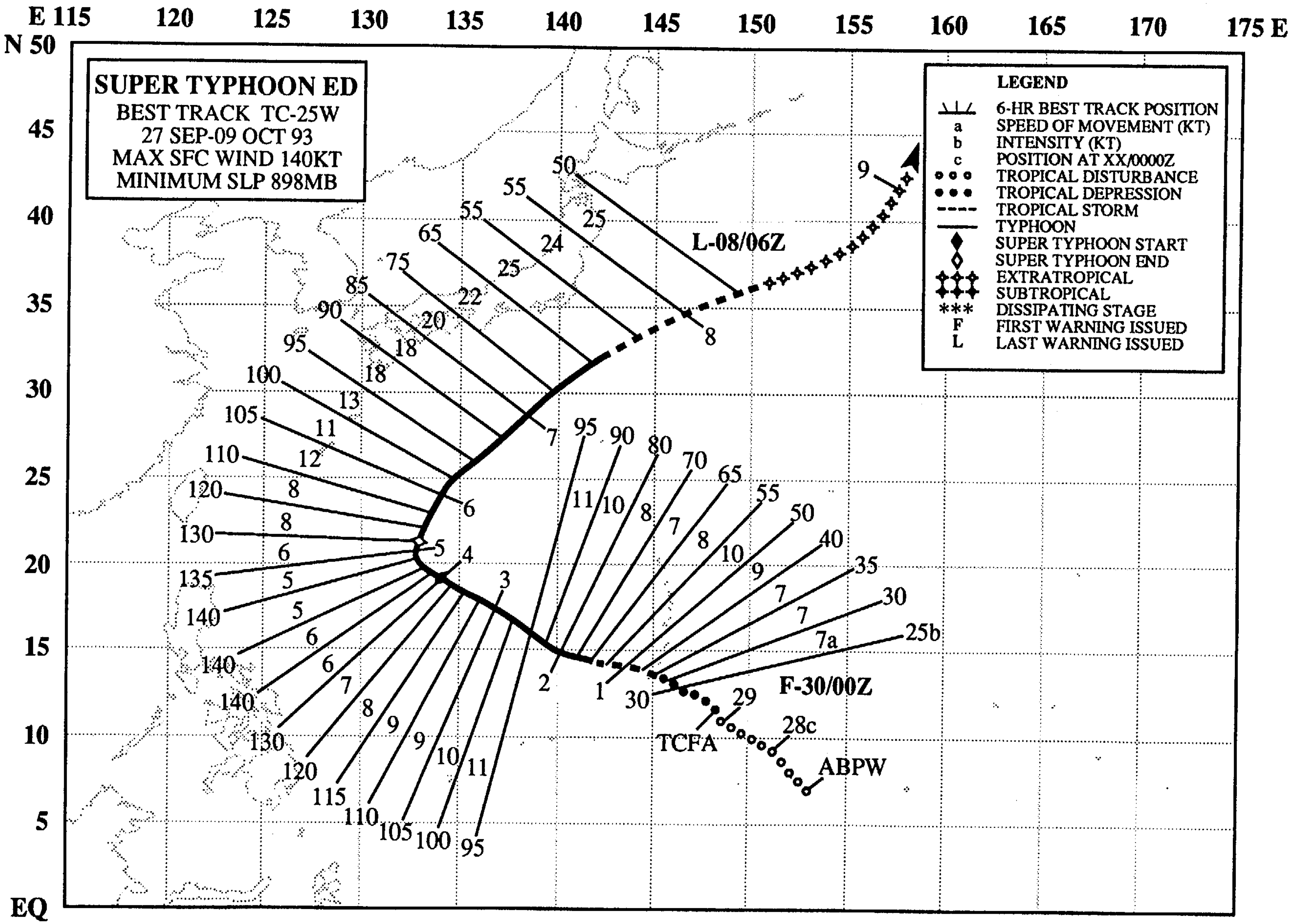
241200Z- Based upon improved convective organization and a satellite intensity estimate of 35 kt (18 m/sec), Dot was upgraded to tropical storm intensity.

250600Z - Following the development of a 25 nm (46 km) cloud filled banding-type eye and a satellite intensity estimate of 65 kt (33 m/sec), Dot was upgraded to typhoon intensity.

270600Z - The final warning was issued on Dot as it dissipated in southern China.

III. IMPACT

News reports stated that seven people were rescued and one person was still missing one day after Dot sunk their fishing vessel near Hong Kong. In addition, with the exception of the international airport, all public transportation in Hong Kong was either curtailed or suspended.


SUPER TYPHOON ED
BEST TRACK TC-25W
27 SEP-09 OCT 93
MAX SFC WIND 140KT
MINIMUM SLP 898MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-08/06Z
F-30/00Z
TCFA
ABPW
E 115
120
125
130
135
140
145
150
155
160
165
170
175 E
N 50
45
40
35
30
25
20
15
10
5
EQ

SUPER TYPHOON ED (25W)

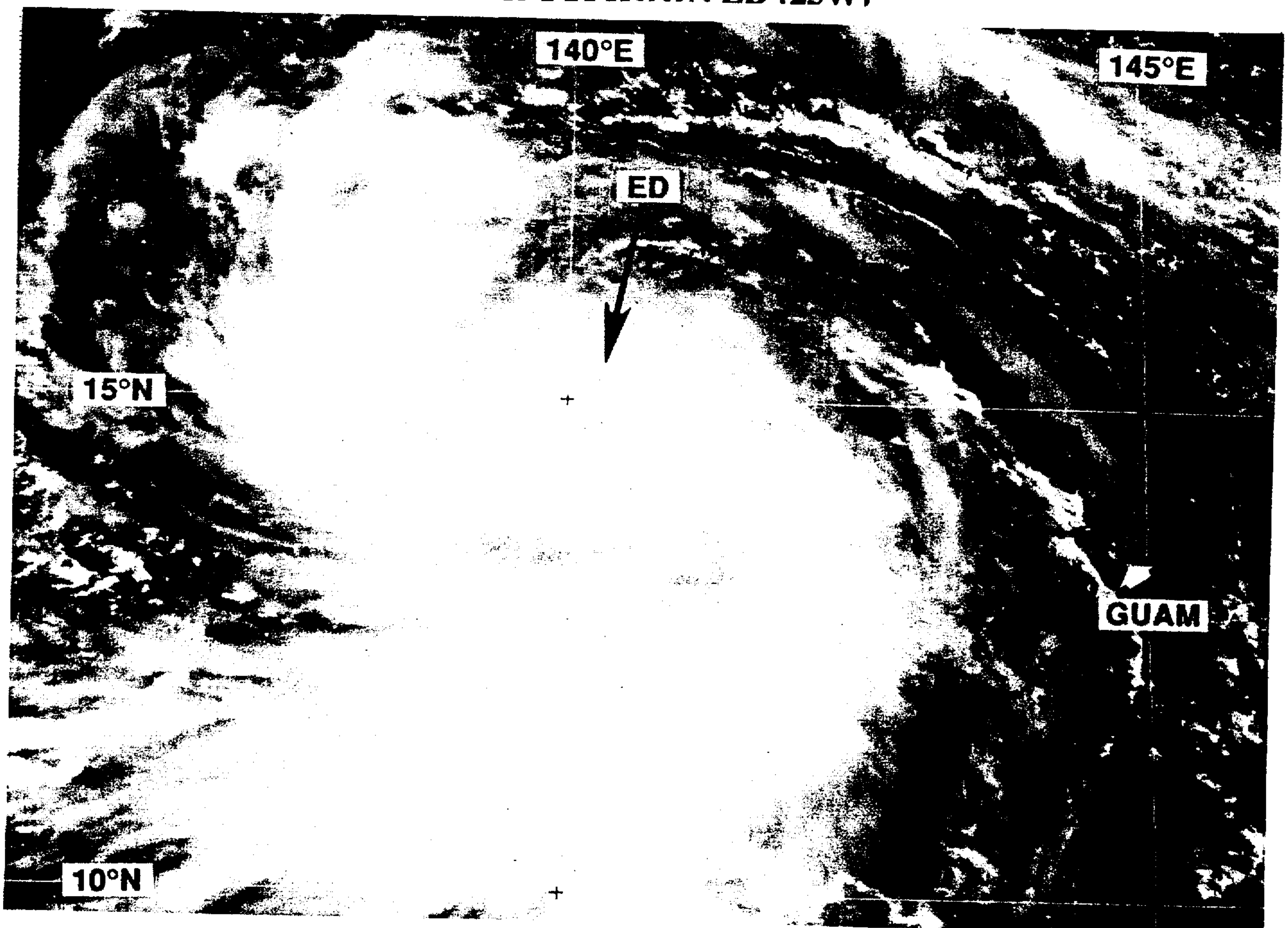


Figure 3-25-1 On the satellite imagery, a small eye becomes visible shortly after Ed reaches typhoon intensity (020031Z October visual GMS imagery).

I. HIGHLIGHTS

The second tropical cyclone to threaten the Mariana Islands within a week, Ed, passed directly over the NEXRAD Doppler weather radar on Guam. Initially forming in the Caroline Islands, Ed steadily developed from a tropical depression to super typhoon intensity within five days. During its intensification from a typhoon to a super typhoon, Ed possessed a small eye (Figure 3-25-1). During most of Ed's lifetime, it underwent binary interaction with Typhoon Flo (26W).

II. CHRONOLOGY OF EVENTS

September

270600Z - An area of persistent convection within the monsoon trough near Chuuk, in the eastern Caroline Islands, resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.

290600Z - A Tropical Cyclone Formation Alert was issued following an increase in convection near an exposed low-level circulation center.

300000Z - The first warning was issued based upon increased convective curvature and a satellite intensity estimate of 25 kt (13 m/sec).

301800Z - Based upon a satellite intensity estimate of 45 kt (23 m/sec), Ed was upgraded to a tropical storm.
October
011200Z - The appearance of a warm spot in the cold CDO and the resulting satellite intensity estimate of 65 kt (33 m/sec) prompted JTWC to upgrade Ed to a typhoon.
040000Z - A small eye deeply embedded in the CDO and a satellite intensity estimate of 127 kt (65 m/sec) led JTWC to upgrade Ed to a super typhoon.
080600Z - The final warning was issued on Ed as it transitioned into an extratropical low well to the east of Japan.

III. IMPACT

Ed brought badly needed heavy rainfall to Guam which resulted in some localized flooding on the island. A peak gust of 53 kt (27 m/sec) was reported at Andersen AFB as the tropical storm passed directly over Guam.

IV. DISCUSSION

a) NEXRAD — The passage of Ed's center over northern Guam, just after it had intensified to a tropical storm, resulted in the first-ever direct passage of a tropical cyclone over a NEXRAD Doppler weather radar. Guam's NEXRAD played a key role in short-term local forecasts as Ed approached the island. About 12 hours prior to landfall on Guam, the velocity dipole, or couplet, associated with the tightly curved wind flow around the small central calm area, became evident on the radial velocity product (RVP) generated by the NEXRAD. Three hours prior to landfall, it became evident from the NEXRAD fixes that Ed's center would pass directly over northern Guam. The RVP showed a small area of gales with an embedded peak velocity of 50 kt (26 m/sec) moving steadily towards the north end of Guam (Figure 3-25-2). Forecasters at Andersen Air Force Base, used this information to give what would turn out to be a very accurate short-range forecast of a brief period of gales with maximum gusts to 50 kt (26 m/sec). Andersen experienced gale-force sustained winds for about a half an hour (from 301230Z to 301300Z September) (Figure 3-25-2d). Wind gusts to 50 kt (26 m/sec) occurred for 10 minutes (1240Z to 1250Z) with a peak gust to 53 kt (27 m/sec) at 1242Z. The light wind core of Ed, during its passage over Guam, is herein referred to as an "eye"; the quotation marks indicating that it did not have an eye in the conventional sense of a central core — free of deep cloud — encircled at least 50% by a wall of tall cumulonimbus cloud. Abruptly, at 1300Z, the winds dropped to 10-15 kt (5-8 m/sec) as the "eye" of Ed passed just to the south of Andersen. These light winds lasted for about 15 minutes as the wind direction veered quickly from 030 degrees to 140 degrees. After the "eye" passage at Andersen, the wind speed increased to 25-30 kt (13-15 m/sec) with gusts to 35 kt (18 m/sec).

The structure of Ed as it passed over Guam, as revealed by the NEXRAD and from eyewitness reports, was very similar to that of a mature tropical cyclone — even though Ed had only just achieved minimal tropical storm intensity. It had a very small "eye" as revealed by the reflectivity pattern (see cover illustration), and its highest winds were packed very tightly along the northern periphery of the "eye". Also, the satellite image at this time showed that Ed possessed a curved band type cloud structure; which, using the Dvorak satellite intensity technique yielded 35 kt (18 m/sec). Nevertheless, the radar reflectivity, the radar Doppler velocity, and the recorded wind and pressure during Ed's passage over Guam all revealed a structure very much like that of a mature tropical cyclone.

The NEXRAD can process its reflectivity data through an algorithm to estimate rainfall rates, which are presented as 1-hour, 3-hour or storm total precipitation products. NEXRAD estimates of storm total

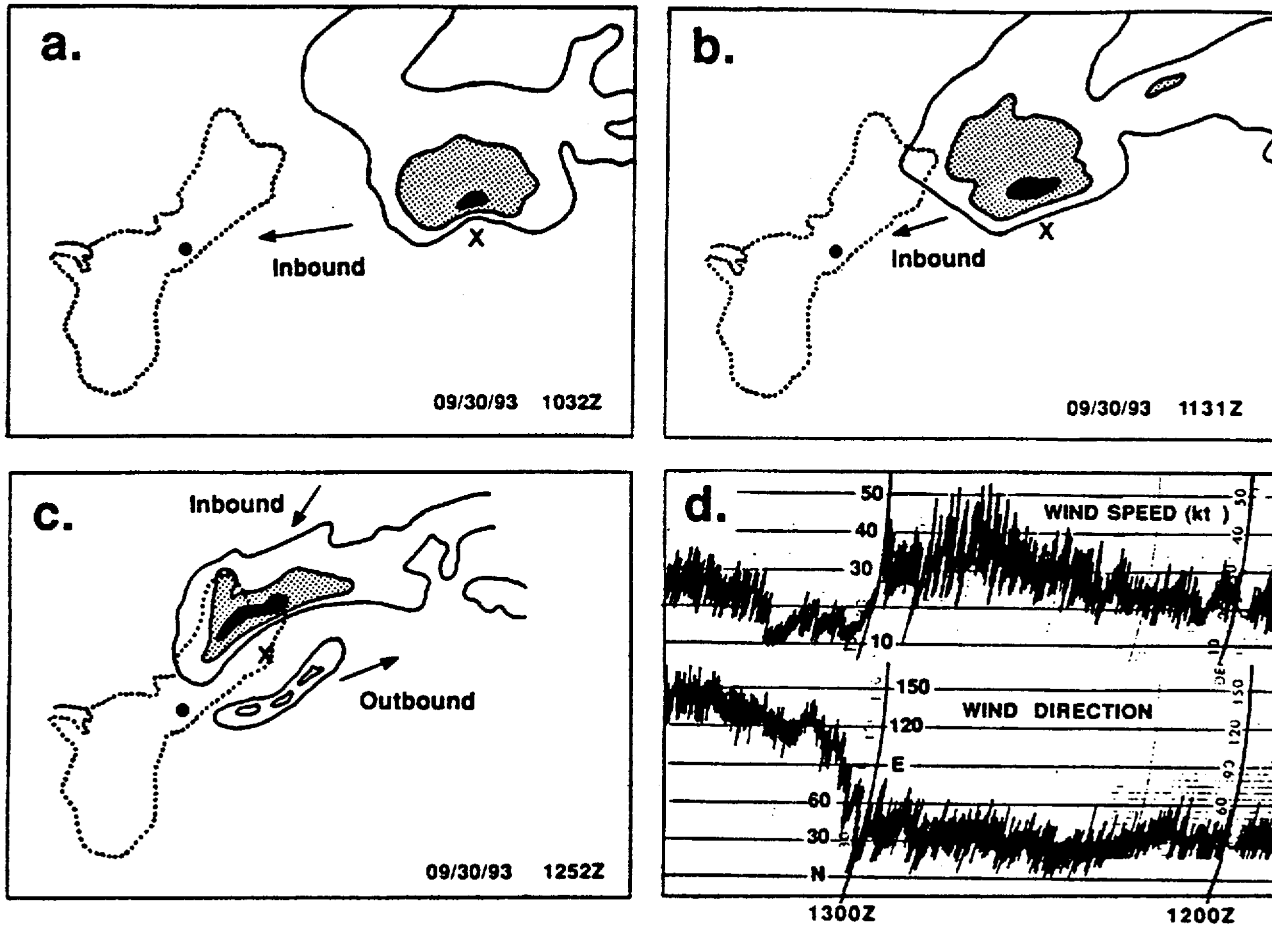


Figure 3-25-2 Radial velocities detected by the NEXRAD Doppler radar as Ed approached Guam: a) Illustration of the radial velocity display for 301032Z, b) 301131Z, c) 301252Z September, and d) the anemometer chart from Andersen AFB (WMO 91218) during the period (301200Z - 301300Z) which includes the gales preceding Ed's landfall. In panels a), b) and c), the outer contour encloses values ≥ 26 kt (13 m/sec), shaded area ≥ 36 kt (19 m/sec), and black areas indicate ≥ 50 kt (26 m/sec). The black dot locates the NEXRAD. Arrows indicate radial velocities as inbound or outbound with respect to the radar. Ed's circulation center is indicated by the x.

precipitation during Ed's passage over Guam (Figure 3-25-3a) were about 50% less than the rainfall actually measured by rain gauges on Guam (Figure 3-25-3b). The gradients of the NEXRAD integrated rainfall agreed with the relative magnitudes of the rainfall at the rain gauges: driest in the northeast of Guam and wettest on the west and southwest of Guam. The large observed error of total integrated rainfall may be due to the algorithm, developed for convective precipitation over the U.S. mainland, brief system outages, or an as yet unknown factor.

b) Binary interaction with Typhoon Flo (26W) — For most of Ed's lifetime it was in close proximity to Typhoon Flo. At their closest point of approach, Ed and Flo were separated by only 670 nm (1240 km) (Figure 3-25-4a and b); well within the 780 nm (1445 km) separation noted by Brand (1970) for cyclone binary interaction. The centroid-relative motion of Ed and Flo (Figure 3-25-4b) exhibited some of the features common to interacting tropical cyclones, see Lander and Holland (1993) (Figure 3-25-4c). For two days (300000Z September to 020000Z October), as both Ed and Flo moved steadily west-northwestward, they remained almost stationary with respect to the centroid-relative reference frame. At 021200Z, the two storms had begun a fairly steady cyclonic orbit and gradually closed to within 670 nm (1240 km) at 040000Z. Coincident with the start of the cyclonic orbit on the 2 October,

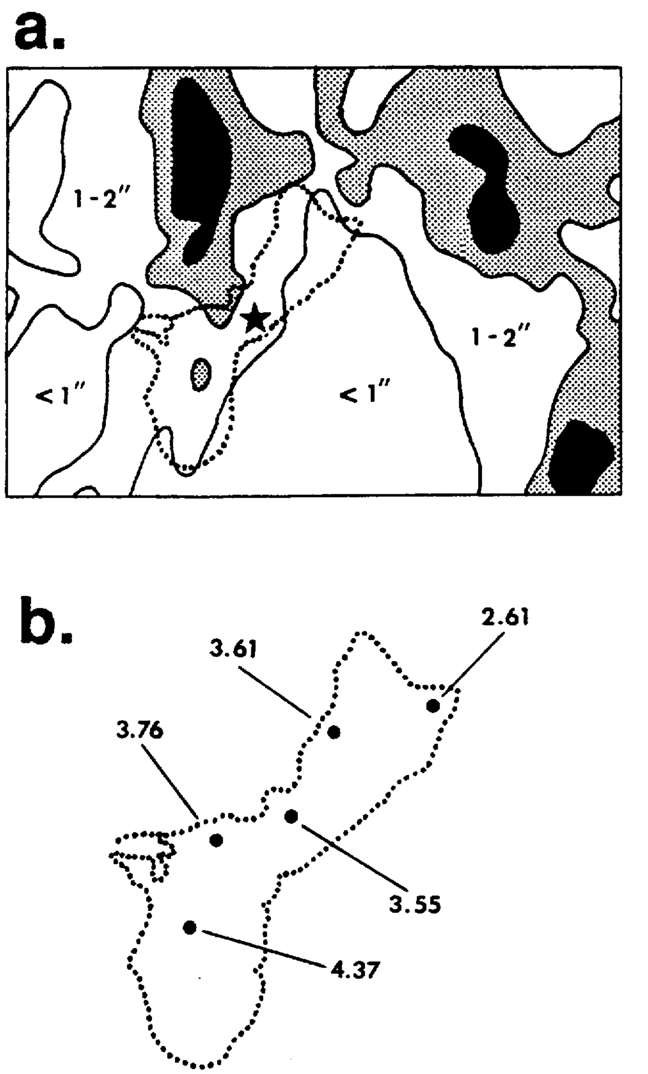


Figure 3-25-3 Total precipitation for Ed's passage over Guam: a) Storm total precipitation estimates from the NEXRAD for the period 282054Z September to 011504Z October. Shaded region = ≥ 2 inches (50 mm), black areas ≥ 3 inches (75 mm). Star locates the NEXRAD. (b) Storm total precipitation measurements from rain gauges for the same period.

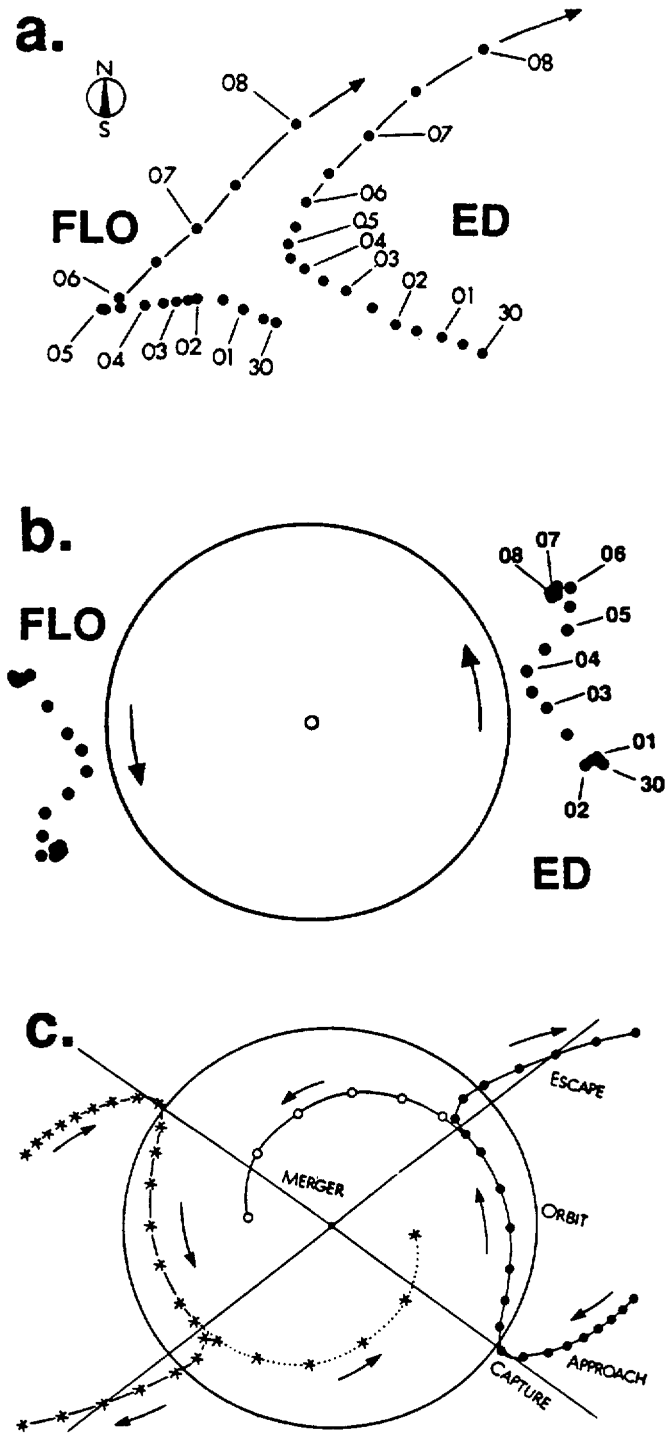
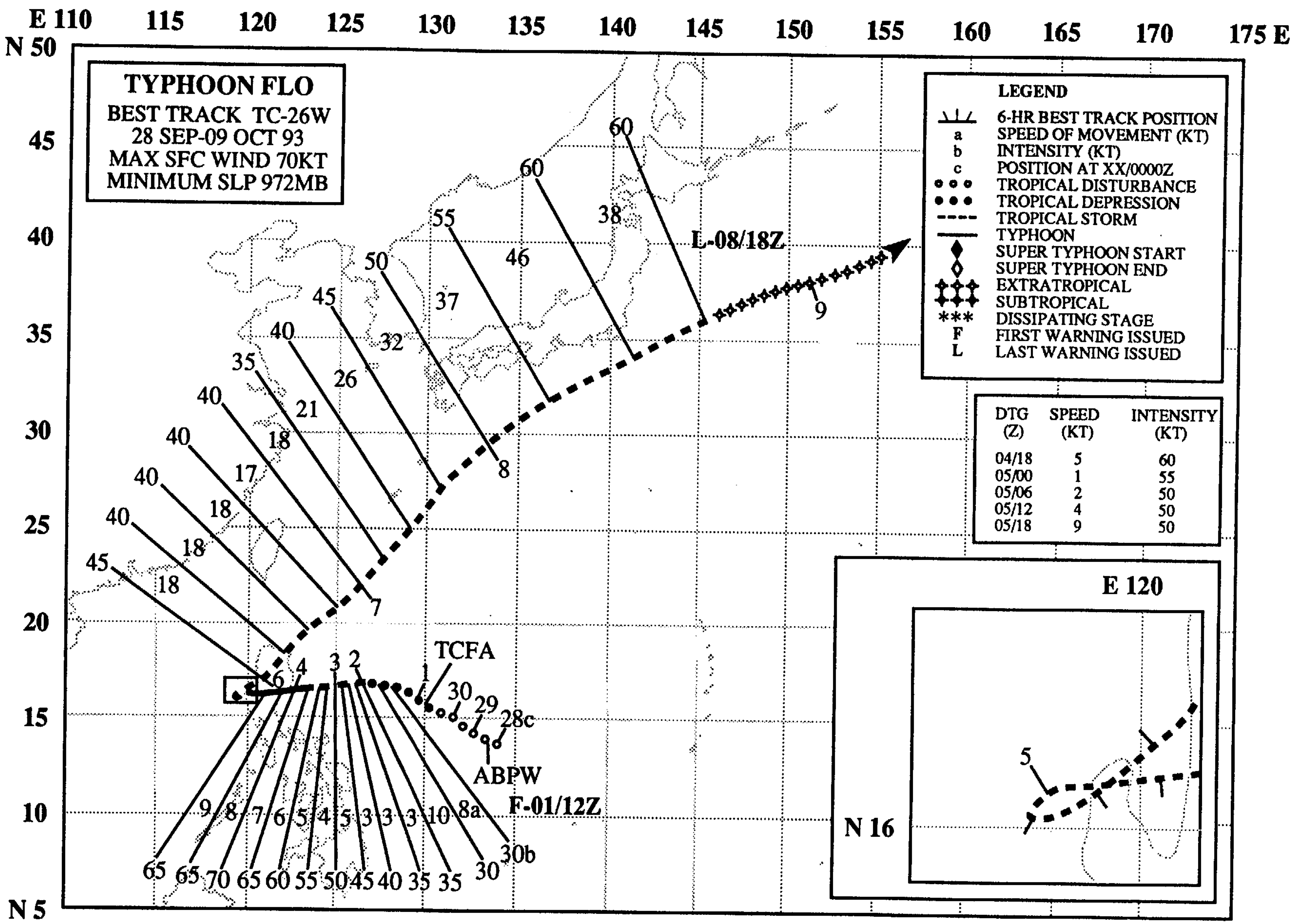


Figure 3-25-4 Binary interaction between Ed and Flo (26W): a) Tracks of Ed and Flo, b) Centroid-relative motion. Circle diameter = 600 nm (1110 km), dots = 12-hour time steps, and dates of 0000Z positions are indicated by 2-digit numbers. (c) Model of binary interaction between two tropical cyclones.

Ed turned a little more to the north and increased it's speed of motion, while Flo slowed its forward speed and turned to follow an unusual west-southwesterly track. The cyclonic orbit ended abruptly at 060000Z as Flo recurved and followed Ed into the midlatitudes on an accelerating northeasterly track. After recurvature, Ed and Flo remained almost stationary in the centroid-relative reference frame.


TYPHOON FLO
BEST TRACK TC-26W
28 SEP-09 OCT 93
MAX SFC WIND 70KT
MINIMUM SLP 972MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
DTG (Z) | SPEED (KT) | INTENSITY (KT)
04/18 5 60
05/00 1 55
05/06 2 50
05/12 4 50
05/18 9 50
TCFA
ABPW
F-01/12Z
L-08/18Z
E 120
N 16

TYPHOON FLO (26W)

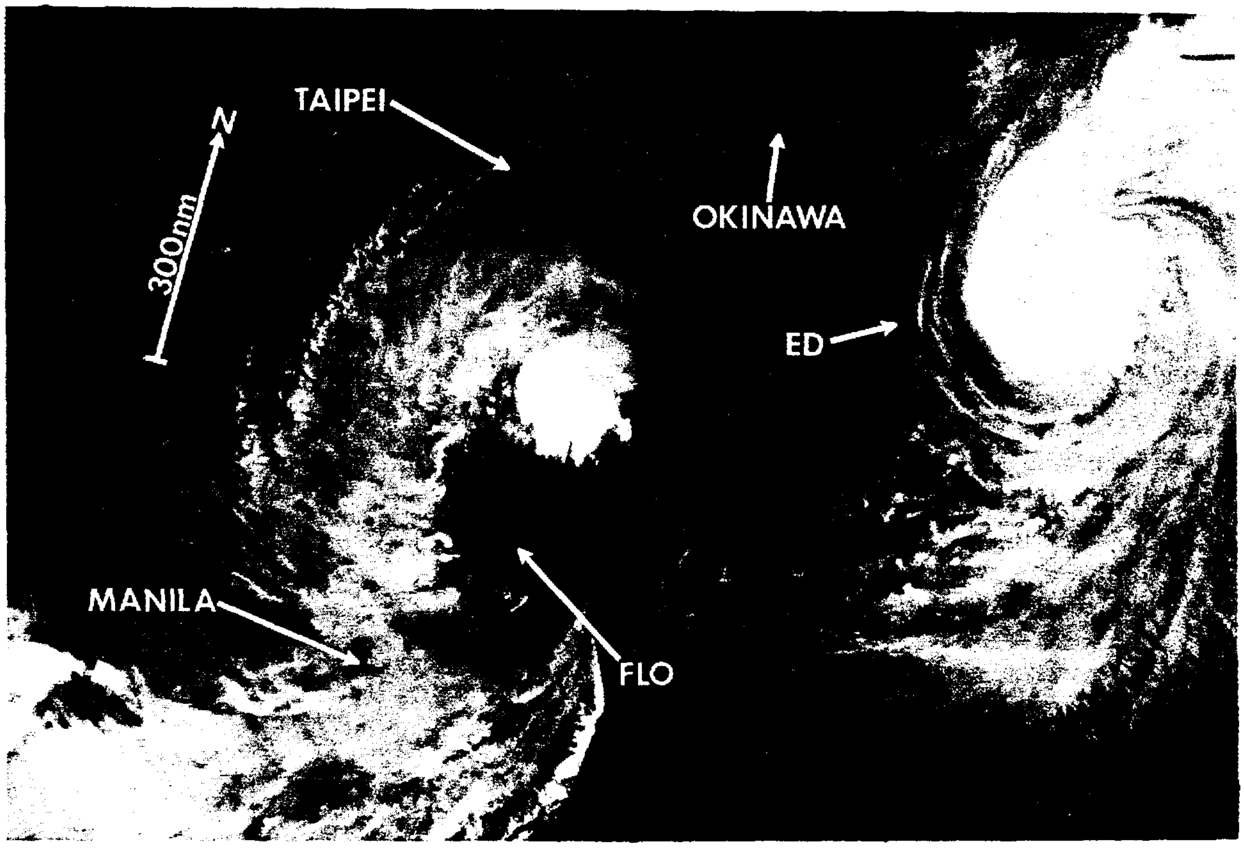


Figure 3-26-1 With the low-level most probably overland and without any central convection, Flo begins its rapid acceleration to the northeast in tandem with Ed (25W) (060640Z October infrared DMSP imagery).

I. HIGHLIGHTS

Forming in the Philippine Sea west Ed (25W), Flo was notable for its binary interaction with Ed. An unanticipated stall, sharp recurvature west of Luzon, and rapid acceleration to the northeast resulted in forecast errors which were the largest of 1993.

II. CHRONOLOGY OF EVENTS

September

280600Z - The disturbance was first mentioned in the Significant Tropical Weather Advisory as a persistent area of convection located within the monsoon trough in the Philippine Sea.

301900Z - Increased deep convection around the well defined low-level circulation center led to issuance of a Tropical Cyclone Formation Alert.

October

011200Z - The first warning was based on a satellite Intensity estimate of 25 kt (13 m/sec).

020000Z - Flo was upgraded to a tropical storm based on the formation of a ragged CDO and resulting satellite intensity estimate of 35 kt (17 m/sec).

031800Z - The appearance of eye and satellite intensity estimate of 65 kt (33 m/sec) led JTWC to upgrade Flo to a typhoon.

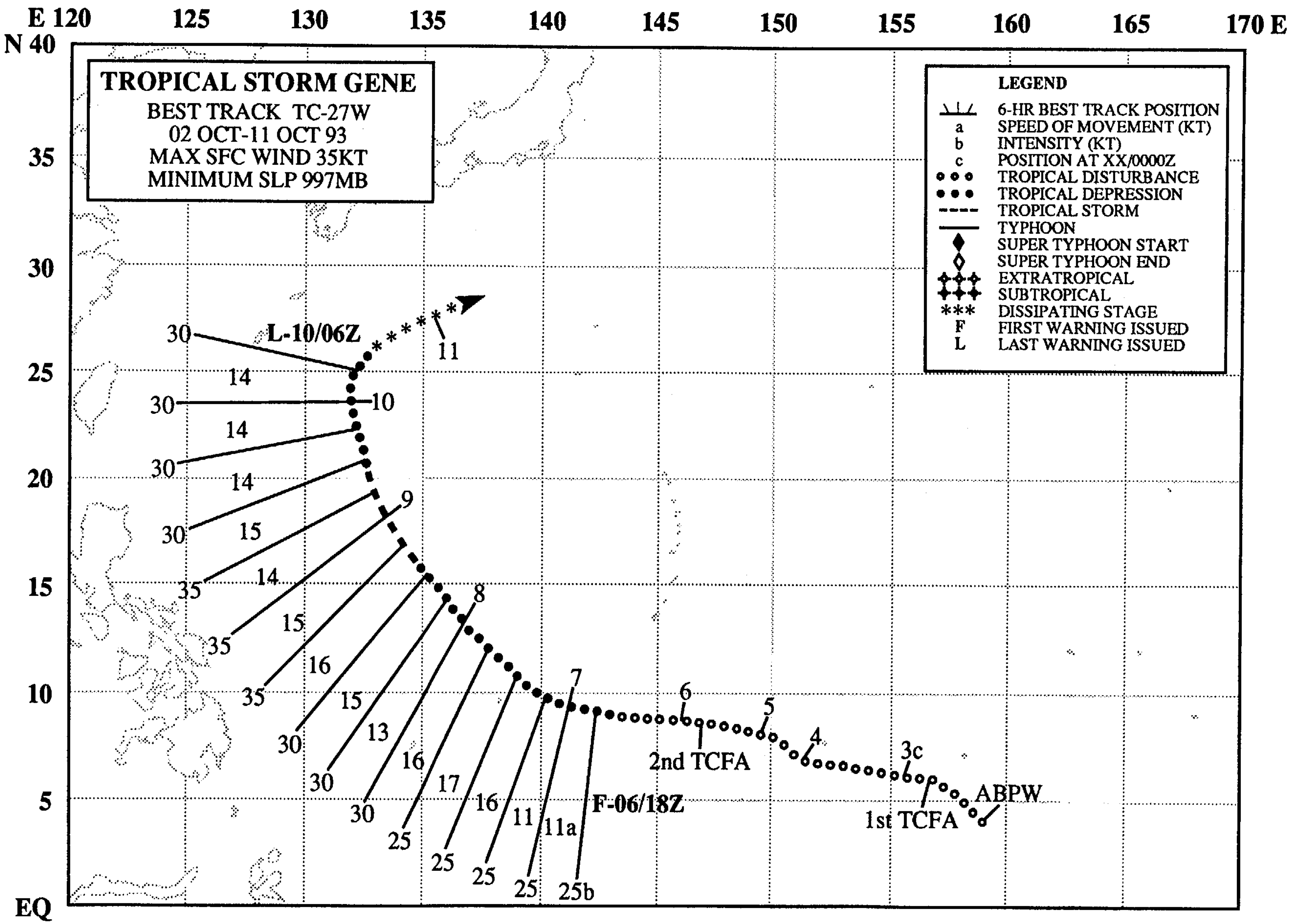
051200Z - Flo unexpectedly recurved, striking Luzon from the west, and afterward, accelerated rapidly toward the northeast.
081800Z - The final warning was issued on Flo as it transitioned into an extratropical low.

III. IMPACT

Torrential rains associated with Flo caused widespread flooding across the island of Luzon in the Philippines. Press reports indicated that at least 50 people were killed or missing, and over 300,000 were evacuated to higher ground. The accelerated motion of Flo, after recurving, to an average speed of 46 kt (85 km/hr) resulted in winds of up to 65 kt (33 m/sec) in the dangerous semicircle. The USS Independence battle group was caught in the dangerous semicircle.

IV. DISCUSSION

A binary interaction occurred between Ed and Flo and appears in the preceding write up on Super Typhoon Ed (25W). With regard to forecast errors, Flo generated the largest 72-hour forecast error — 1732 nm (154 km) — of the year. Flo's stall, loss of central convection (Figure 3-26-1), recurvature and subsequent rapid acceleration compounded the forecasting problem. Objective guidance, including the dynamic models, had difficulty handling the track changes. As these events occurred, forecasters indicated low confidence in their forecasts.


TROPICAL STORM GENE
BEST TRACK TC-27W
02 OCT-11 OCT 93
MAX SFC WIND 35KT
MINIMUM SLP 997MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 120
125
130
135
140
145
150
155
160
165
170 E
N 40
35
30
25
20
15
10
5
EQ
L-10/06Z
F-06/18Z
2nd TCFA
1st TCFA
ABPW
11a
25b
3c

TROPICAL STORM GENE (27W)

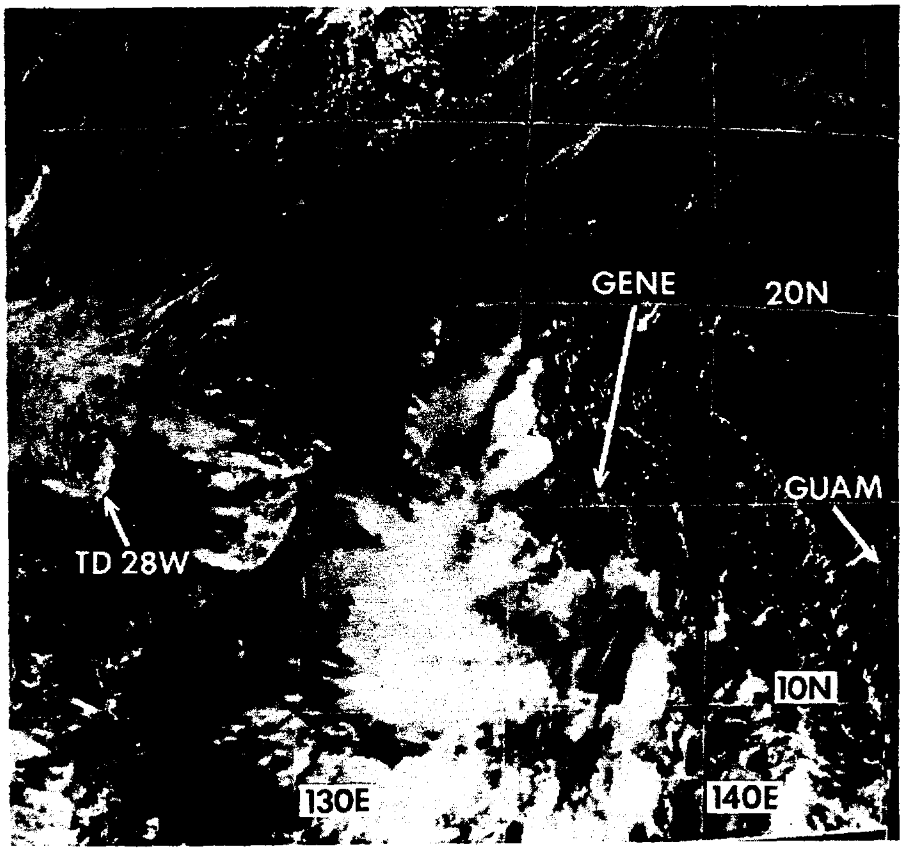


Figure 3-27-1 Cloud lines outline the exposed low-level circulation center of Gene about 12 hours before it was upgraded to tropical storm intensity (080424Z October visible DMSP imagery).

I. HIGHLIGHTS

Occurring during a multiple storm outbreak that included Super Typhoon Ed (25W), Typhoon Flo (26W), and Tropical Depression 28W), Gene was the first of five significant tropical cyclones to form during October. During a four-day evolution, Gene slowly transitioned from a wave in the easterlies into a tropical depression, while passing south of Guam. Briefly attaining tropical storm intensity, Gene (Figure 3-27-1) followed a northward track, and ultimately dissipated over water, east of Okinawa.

II. CHRONOLOGY OF EVENTS

October

020600Z - An area of persistent convection, associated with a wave in the easterlies south of the Caroline Islands, resulted in the first discussion of the disturbance in the Significant Tropical Weather Advisory.

021930Z - Increased convective organization led to the issuance of a Tropical Cyclone Formation Alert (TCFA).

031930Z -A decrease in convection during the TCFA, led to its cancellation.

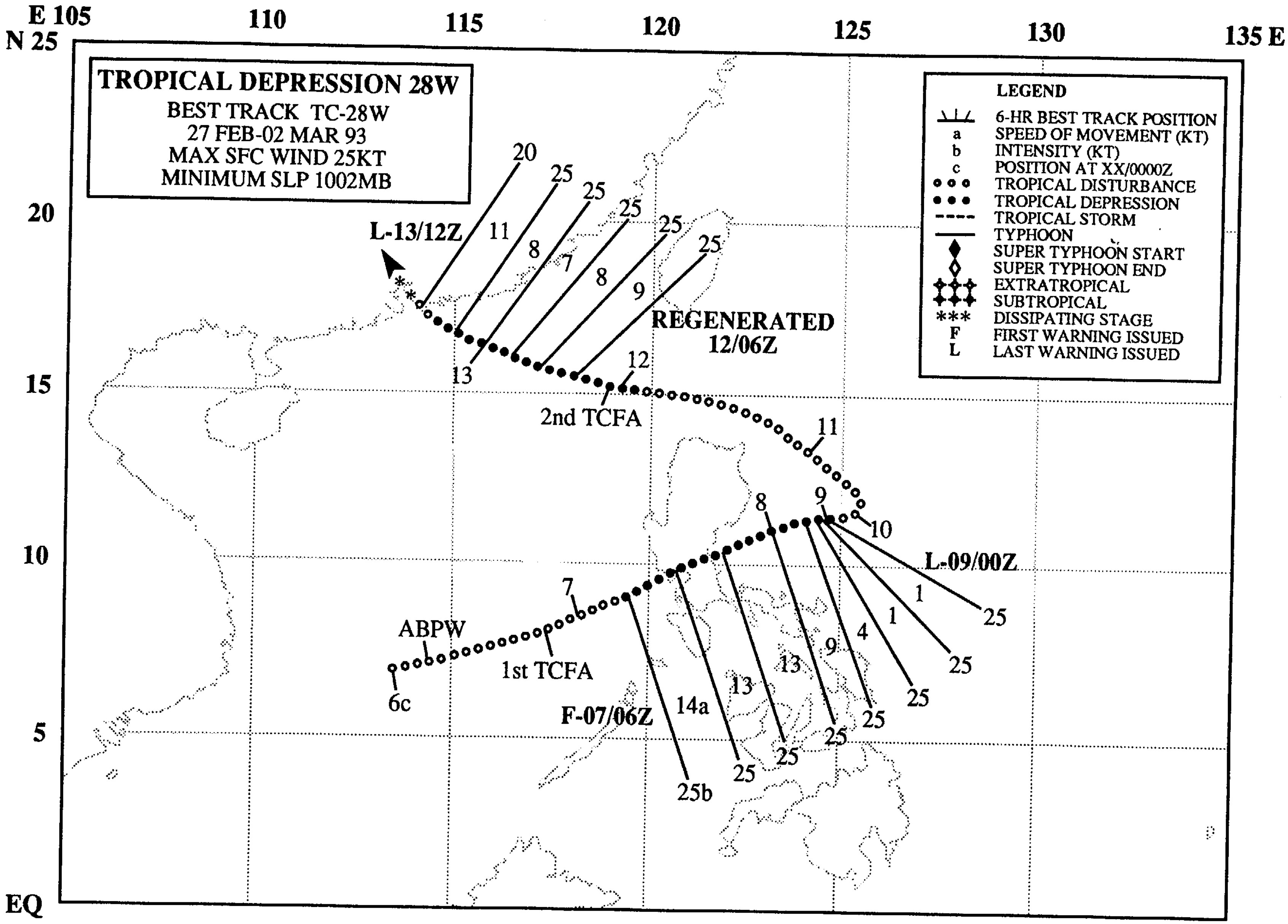
052000Z - Increased convection near the circulation center, prompted the issuance of a second TCFA.

061800Z - The first warning was issued based on a satellite intensity estimate of 25 kt (13 m/sec).

081800Z - Despite strong persistent upper level wind shear, Gene was upgraded to tropical storm intensity based on a satellite intensity estimate of 35 kt (18 m/sec).
100600Z - The final warning was issued on Gene as it dissipated over water east of Okinawa.

III. IMPACT

None.



E 105
110
115
120
125
130
135 E
N 25
20
15
10
5
EQ
TROPICAL DEPRESSION 28W
BEST TRACK TC-28W
27 FEB-02 MAR 93
MAX SFC WIND 25KT
MINIMUM SLP 1002MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-13/12Z
REGENERATED 12/06Z
2nd TCFA
L-09/00Z
ABPW
1st TCFA
F-07/06Z
6c
14a
25b

TROPICAL DEPRESSION 28W

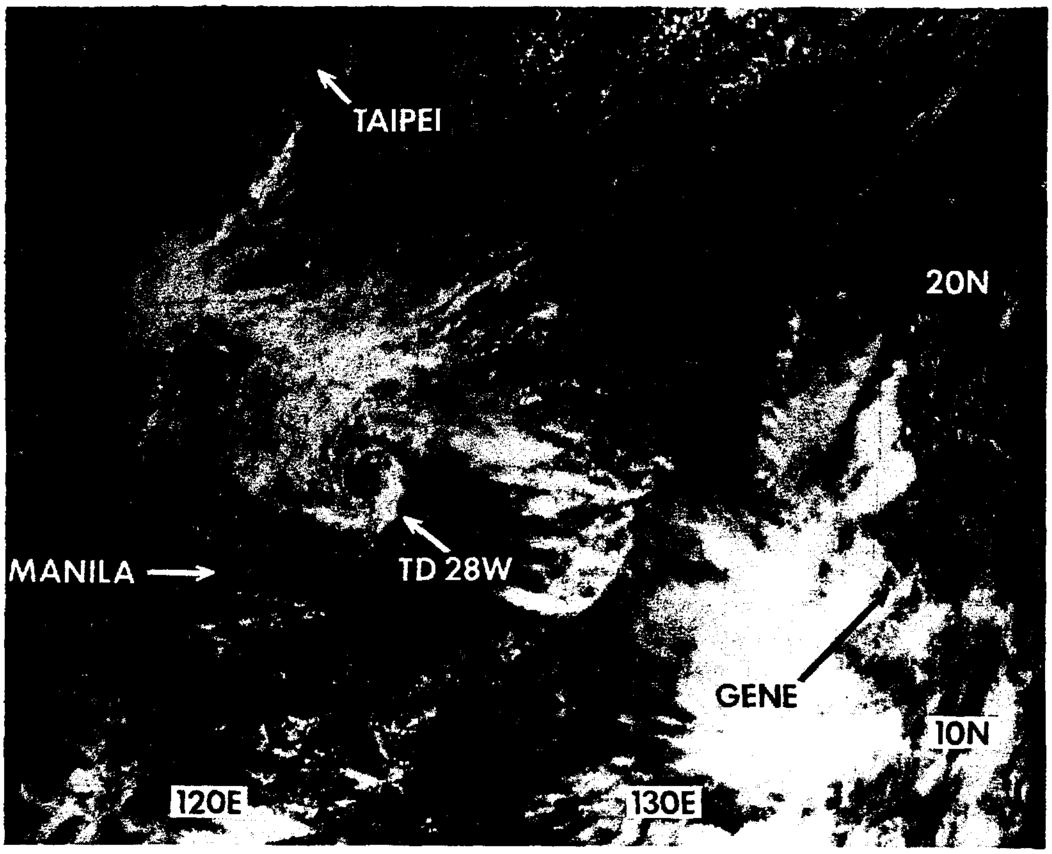


Figure 3-28-1 The exposed low-level circulation center of TD 28W is visible to the east of Luzon. Most of the deep convection associated with the depression subsided after crossing Luzon 12 hours earlier (080424Z October visual DMSP imagery).

I. HIGHLIGHTS

Caught in strong monsoonal flow, Tropical Depression 28W (TD 28W) initially moved northeastward toward Luzon, in the wake of Super Typhoon Ed (25W) and Typhoon Flo (26W). Persistent, yet weak, TD 28W remained at tropical depression intensity while crossing Luzon and moving into the Philippine Sea where it dissipated 24 hours later (Figure 3-28-1). After the remnants of TD 28W turned northwestward on 10 October, the tropical cyclone regenerated. TD 28W made landfall just to the west of Hong Kong and dissipated in southern China.

II. CHRONOLOGY OF EVENTS

October

060600Z - An area of persistent convection within the monsoon trough, near the Vietnam coastline, resulted in the first discussion of the disturbance in the Significant Tropical Weather Advisory.

062000Z - A Tropical Cyclone Formation Alert (TCFA) was issued based on an increase in convection near the circulation center.

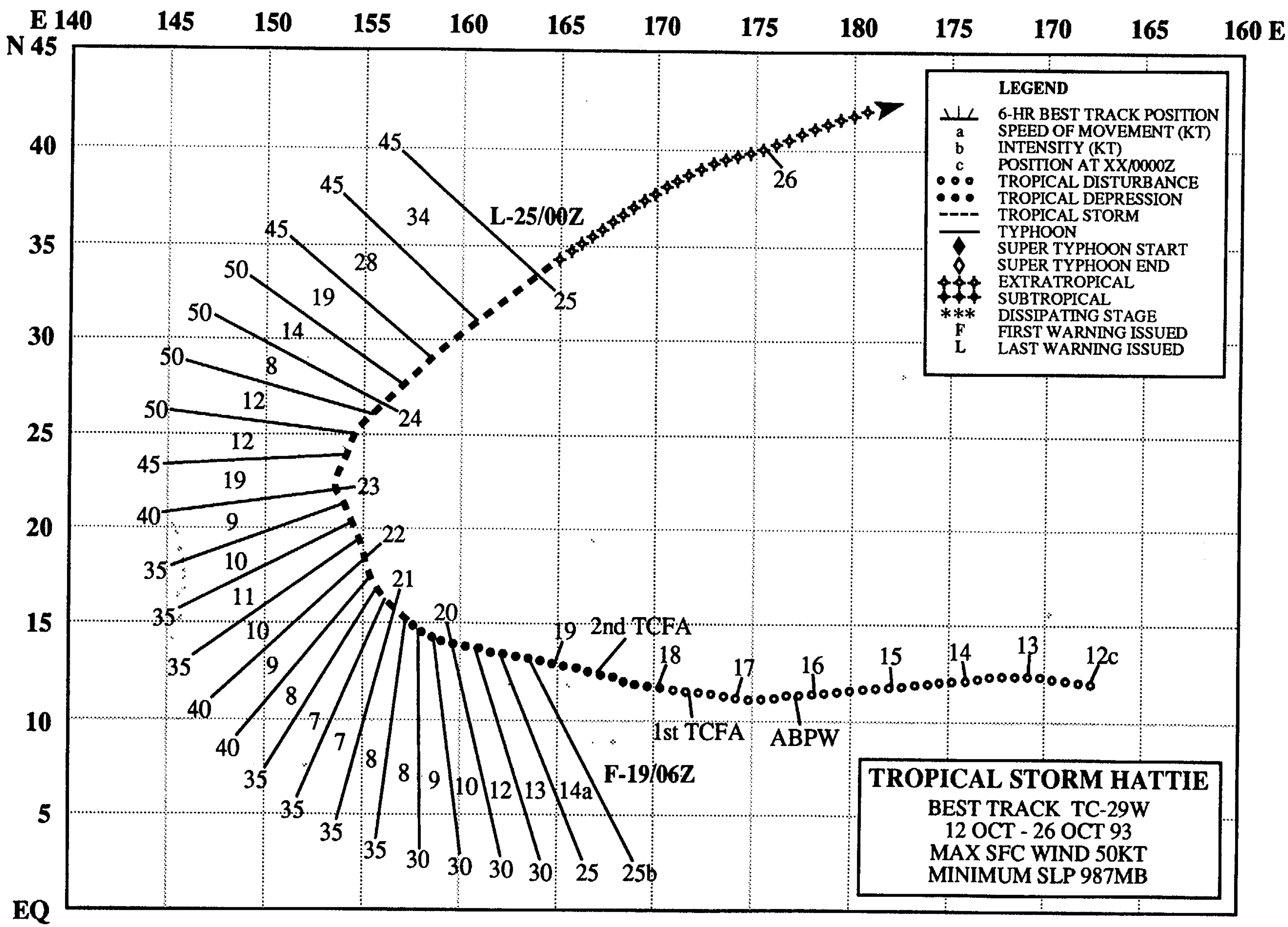
070600Z - The first warning was issued on TD 28W based upon a satellite intensity estimate of 25 kt (13 m/sec).

090000Z - The first final warning was issued as the system dissipated over water, leaving behind a diffuse, low-level circulation center.

120200Z - A second TCFA was issued following flare-ups of intermittent deep convection over the low level circulation center.
120600Z - Warnings were reissued as convective organization improved while the system tracked toward Hong Kong.
131200Z - The final warning of the regenerated system was issued as the system quickly dissipated after passing over land in the vicinity of Hong Kong.

III. IMPACT

None.


LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-25/00Z
F-19/06Z
1st TCFA
2nd TCFA
ABPW
TROPICAL STORM HATTIE
BEST TRACK TC-29W
12 OCT - 26 OCT 93
MAX SFC WIND 50KT
MINIMUM SLP 987MB

TROPICAL STORM HATTIE (29W)

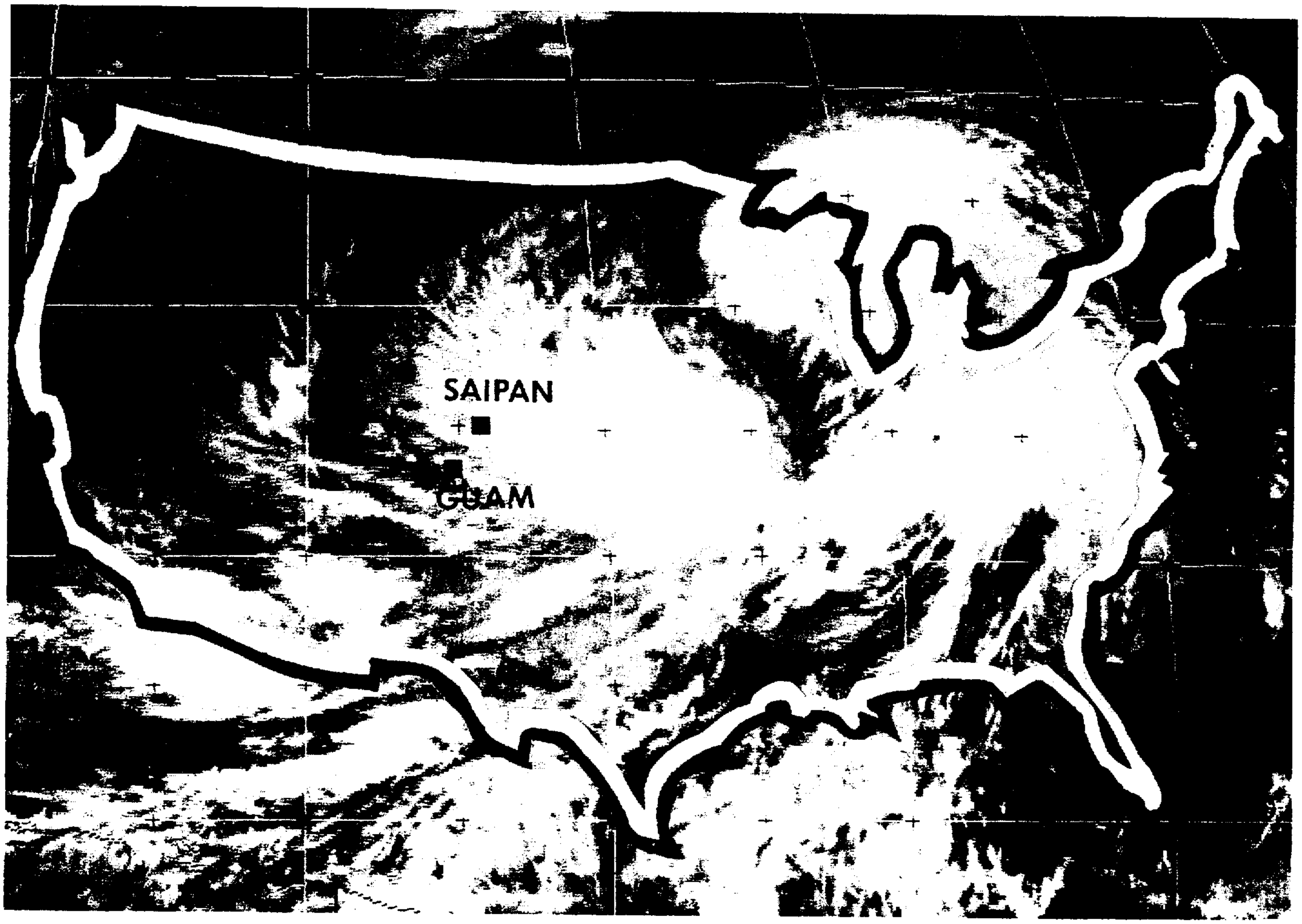


Figure 3-29-1 An outline of the U.S. mainland superimposed (to-scale) upon an infrared image of Hattie (220030Z October infrared GMS imagery).

I. HIGHLIGHTS

Hattie started as a large monsoon depression. Five Tropical Cyclone Formation Alerts were issued — three by the Central Pacific Hurricane Center (CPHC) and two by the JTWC — before the first warning was issued. The system was unique because of its cloud structure: a large 100-160 nm (200-300 km) diameter central area remained relatively cloud-free while convective cloud clusters were peppered throughout the periphery of the circulation in an area equal in size to the continental United States (see Figure 3-29-1).

II. CHRONOLOGY OF EVENTS

October

160600Z - The tropical disturbance was first mentioned of the in the Significant Tropical Weather Advisory as a region of loosely organized convection associated with a large monsoon depression near the international date line.

171630Z - The first JTWC Tropical Cyclone Formation Alert (TCFA) issued was based upon an increase in convection and improved convective curvature.

181630Z - A second TCFA (fifth overall) followed after the system failed to intensify.
190600Z - The first warning was issued based upon numerous synoptic reports of 25 kt (13 m/sec) in a peripheral wind band encircling a large light-wind core.
201800Z - The upgrade to a tropical storm was based upon surface synoptic reports of winds up to 35 kt(13 m/sec) within the peripheral wind band.
250000Z - The final warning was issued on Hattie as it transitioned into an extratropical low.

III. IMPACT

The island of Pohnpei in the eastern Caroline Islands reported minor damage to vegetation and structures.

IV. DISCUSSION

From a diagnostic standpoint, Hattie was one of the most problematical tropical cyclones of 1993. Hattie evolved from a large monsoon depression which formed in the Marshall Islands during mid-October. A "monsoon depression" is distinguished from other types of tropical cyclones by the following characteristics (see also the definition in Appendix A):

1) a large-sized depression in the surface pressure field with a radius of the outermost closed isobar (ROCI) on the order of 300 nm (555 km);

2) extensive amounts of convective cloud elements loosely organized within the confines of the cyclonic vortex; however, the circulation center lacks a persistent convective feature that would lend itself to the Dvorak intensity analysis technique; and,

3) a wind field that features a large, 100-160 nm (200-300 km) diameter, light-wind core which is surrounded wholly, or in part, by bands of higher, 25-35 kt (13-18 m/sec) wind.

The monsoon depression which became Tropical Storm Hattie was large; a composite chart of its sea-level pressure was constructed from surface observations taken during the period 181200Z to 200000Z October (Figure 3-29-2). The ROCI during the composite period was 430 nm (800 km) north-south and 755 nm (1400 km) east-west. The cloud field associated with Hattie during the composite period exhibited a large core region which was relatively cloud free surrounded by extensive clusters and bands of deep cumulonimbus clouds. The structure of the wind field at this time featured a large core of relatively light wind (which was collocated with the relatively cloud-free core in the satellite image) surrounded by an extensive area of 25-30 kt (13-15 m/sec) wind outward for up to 540 nm (1000 km) clockwise from northwest to southwest.

Hattie presented two diagnostic problems to the JTWC. The first problem was that since it lacked persistent central convection, and the Dvorak technique for the estimation of tropical cyclone intensity from satellite imagery does not apply. Attempts were made, however, to apply the technique to one of several of Hattie's persistent peripheral cloud clusters. Finally, however, as Hattie turned northward, a distinct and centrally located low-level circulation center became apparent (Figure 3-29-3), and the Dvorak technique applied.

The second diagnostic problem was determining whether the disturbance (which was to become Hattie) was a monsoon depression or a monsoon gyre (see Appendix A for complete definitions of these terms and Figure 3-29-4). As a monsoon depression, the disturbance would be expected to evolve eventually into a conventional, but large, tropical cyclone. As a monsoon gyre, the disturbance would be expected to evolve into a large "fish-hook" shaped cloud band which would produce a series of small tropical cyclones. In retrospect, the option to go with the synoptic pattern as a monsoon depression was correct.

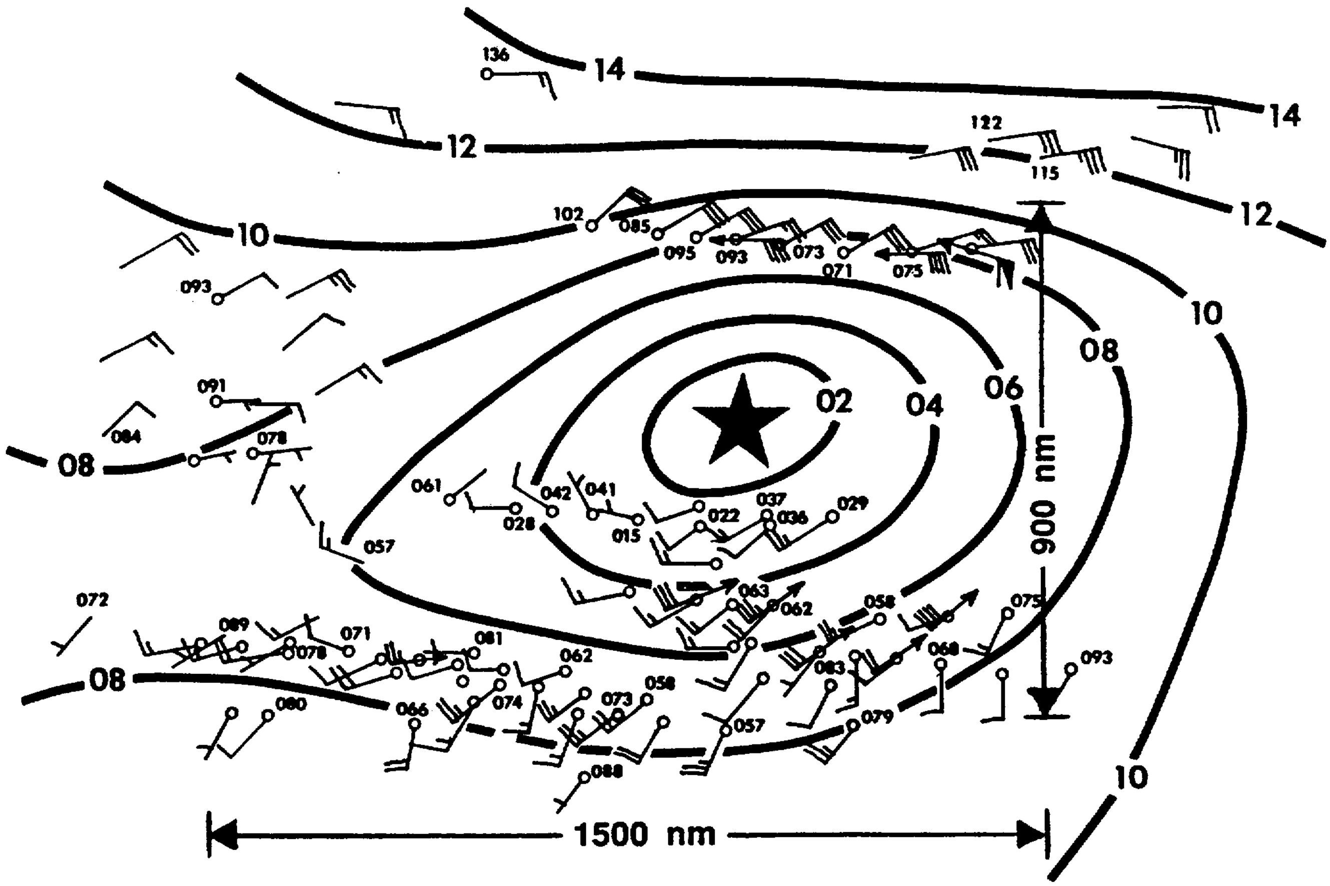


Figure 3-29-2 Isobaric analysis of the sea-level pressure constructed from a composite of observations plotted with respect to the moving center of Hattie (large star). Contour interval is 2 mb, and data are for 181200Z - 200000Z.

In summary, the Dvorak technique shouldn't be applied to monsoon depressions. For the present, the intensity and areal extent of the peripheral winds must be obtained from conventional synoptic data or from cloud-drift winds. A Dvorak-type technique could be developed to address intensity estimation and wind distribution in the monsoon depression. Other spectral windows than the visual and infrared, such as the SSM/I, may be exploited. The differential diagnosis between "monsoon depression" and "monsoon gyre" is important for its forecast implications; and, in the case of Hattie, a careful analysis of the structural characteristics led to a useful diagnosis of the pre-Hattie disturbance as a monsoon depression.

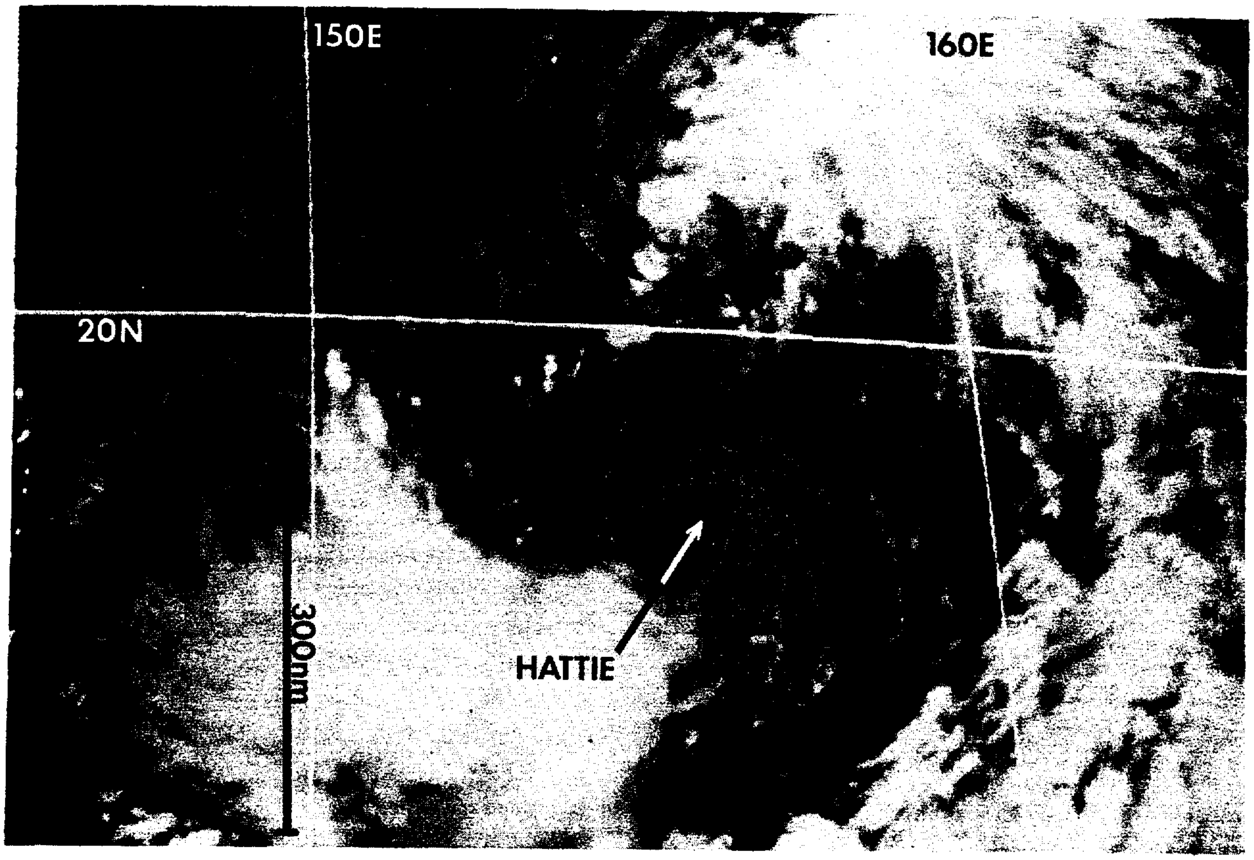


Figure 3-29-3 Hattie's exposed low-level circulation center (LLCC) appears between two areas of extensive convective cloudiness (220031Z October multispectral visual/infrared GMS imagery).

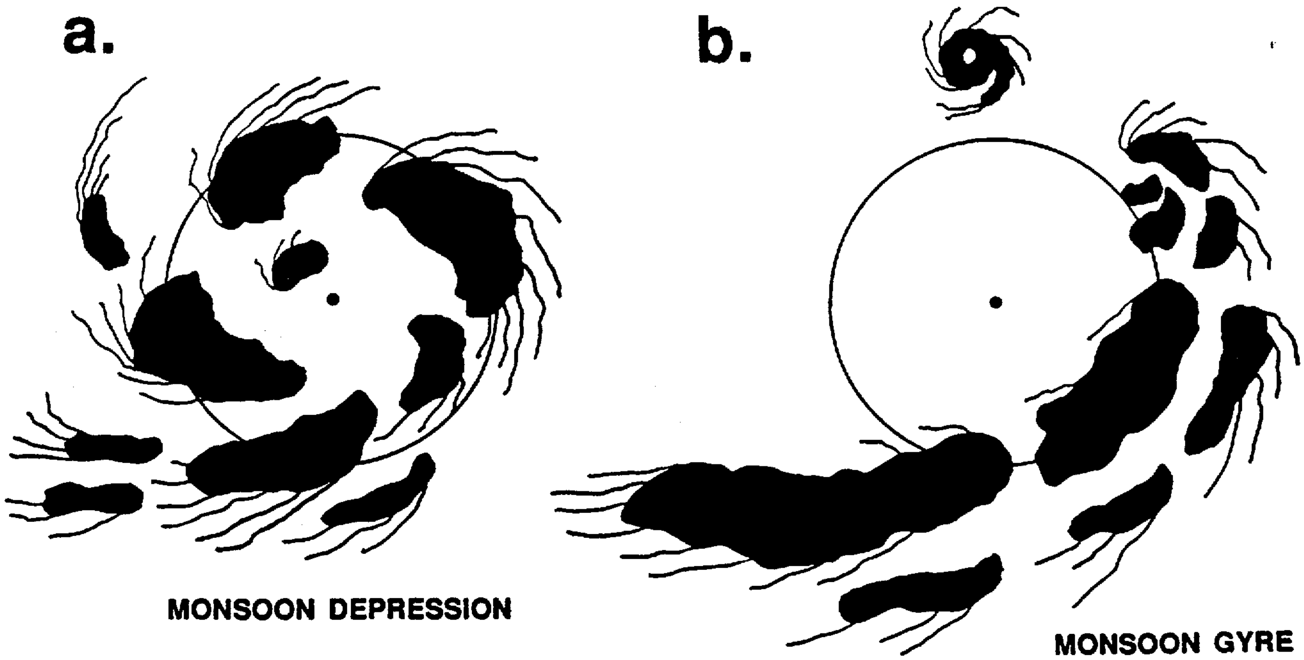
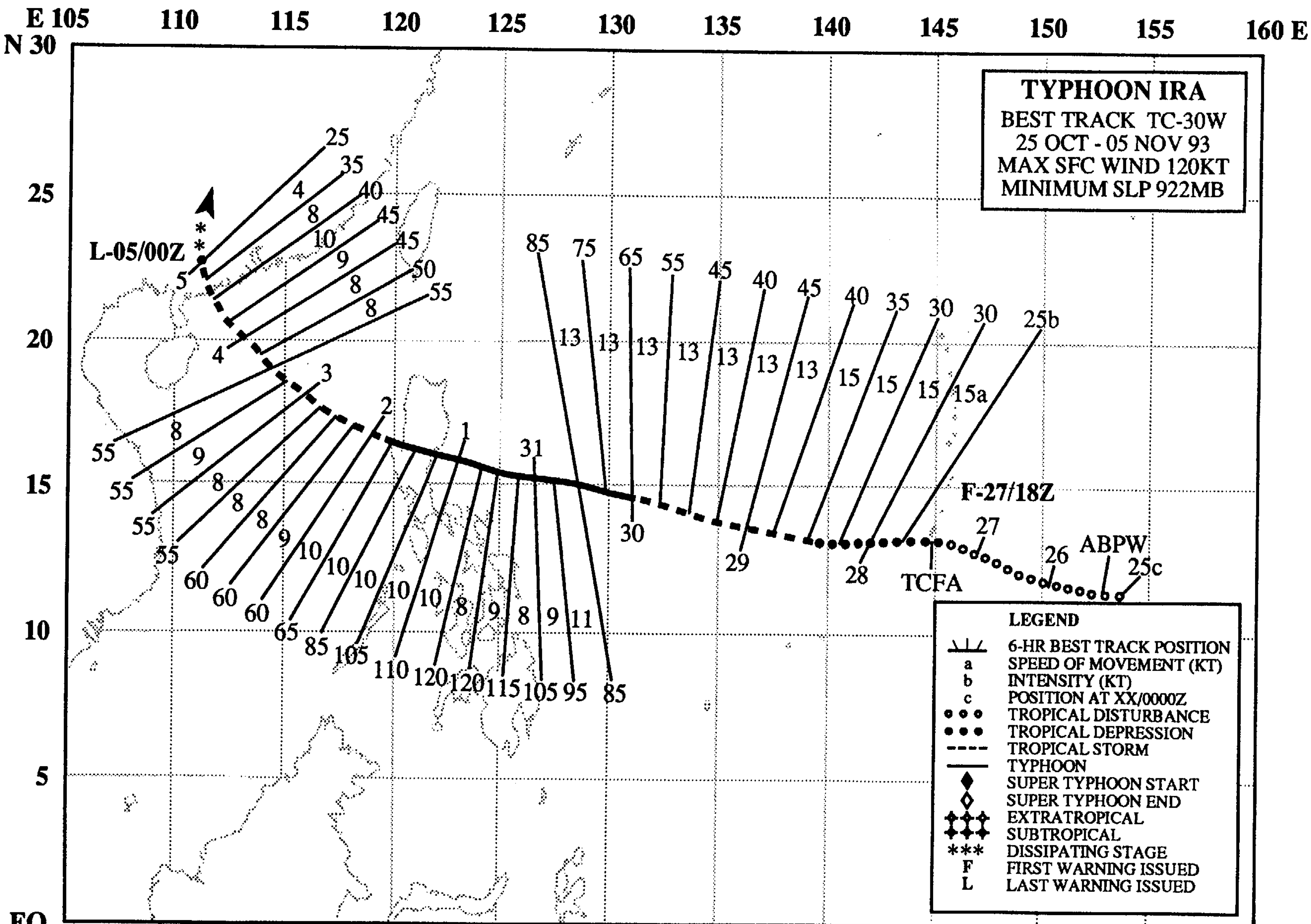


Figure 3-29-4 Schematic illustration of the distribution of deep convective cloud and cirrus in: a) a monsoon depression, and b) a monsoon gyre. Black areas represent deep convection, and filaments indicate orientation of cirrus plumes. Circle enclosed area of lowest sea-level pressure and has a diameter of approximately 600 nm (1110 km). The black dot is the low-level circulation center.


TYPHOON IRA
BEST TRACK TC-30W
25 OCT - 05 NOV 93
MAX SFC WIND 120KT
MINIMUM SLP 922MB
E 105
110
115
120
125
130
135
140
145
150
155
160 E
N 30
25
20
15
10
5
EQ
L-05/00Z
F-27/18Z
TCFA
ABPW
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON IRA (30W)

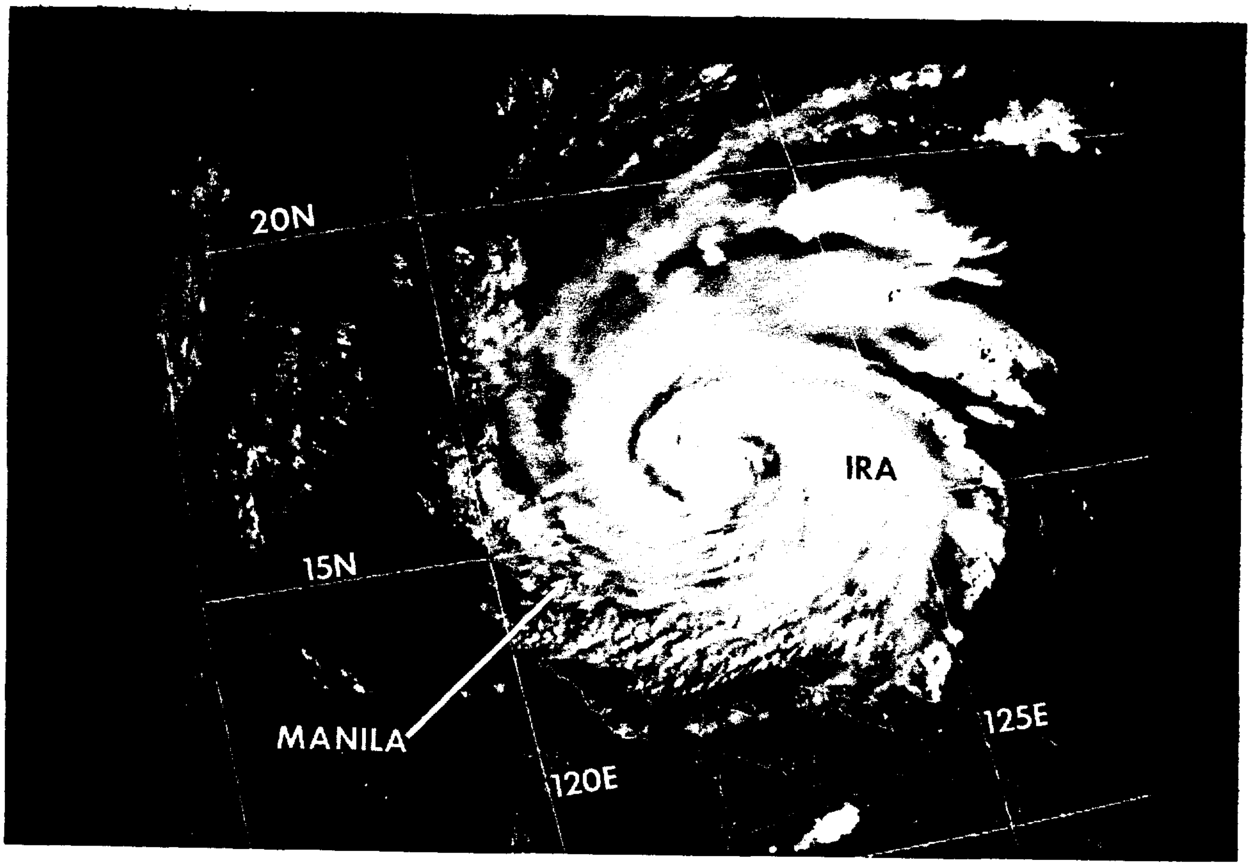


Figure 3-30-1 Typhoon Ira shortly before making landfall in Luzon with maximum sustained winds estimated at 110 kt (57 m/sec) (010121Z November visible DMSP imagery).

I. HIGHLIGHTS

The final tropical cyclone to form during October, Ira, passed directly over Luzon at typhoon intensity and followed a westward track (Figure 3-30-1). Upon entering the South China Sea, a weaker Ira turned toward southern China and made landfall three days later southwest of Hong Kong.

II. CHRONOLOGY OF EVENTS

October

250600Z - An area of persistent convection associated with a weak cyclonic circulation within the monsoon trough, north of the Caroline Islands, resulted in the initial identification of the disturbance in the Significant Tropical Weather Advisory.

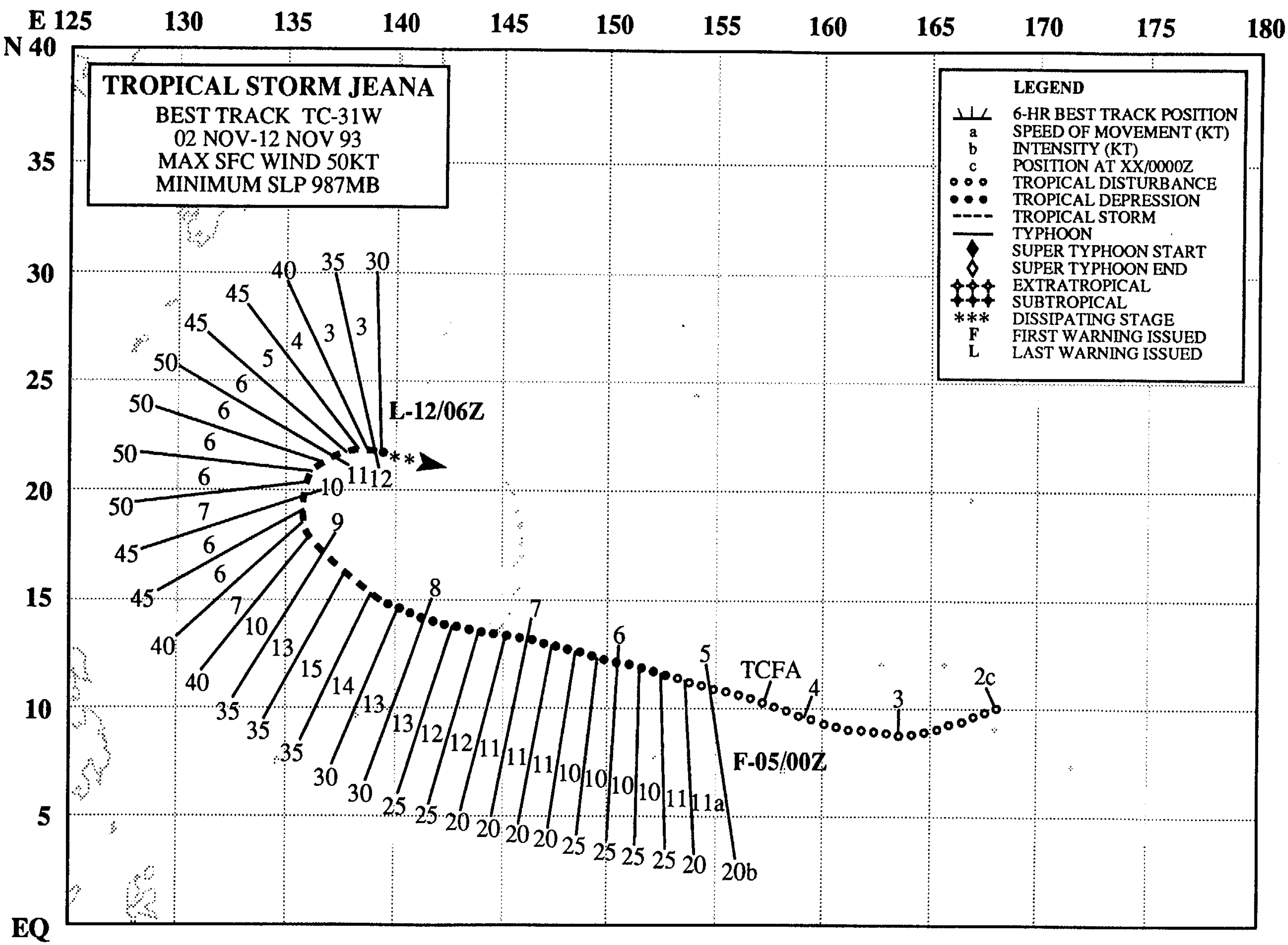
271200Z - A Tropical Cyclone Formation Alert was issued based on an increase in convection and convective curvature, evident in both infrared satellite imagery and on the NEXRAD Doppler Radar located on Guam.

271800Z - The basis of thefirst warning was a satellite intensity estimate of 25 kt (13 m/sec) and Doppler radar velocity information which indicated winds ranging from 22-30 kt (11-15 m/sec) at altitudes of 1500 to 16,000 feet (460 to 4900 meters) above sea level.

281200Z - Based on a satellite intensity estimate of 35 kt (18 m/sec), Ira was upgraded to a tropical storm.
300000Z - Ira was upgraded to a typhoon based on a satellite intensity estimate of 77 kt (40m/sec).
November
050000Z - The final warning was issued after the system made landfall in southern China where it rapidly dissipated.

III. IMPACT

News reports attributed eight deaths in the Philippines to Typhoon Ira's trek across central Luzon. In addition, heavy rains associated with the typhoon also caused extensive flooding in low-lying areas of Luzon.


TROPICAL STORM JEANA
BEST TRACK TC-31W
02 NOV-12 NOV 93
MAX SFC WIND 50KT
MINIMUM SLP 987MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 125
130
135
140
145
150
155
160
165
170
175
180
N 40
35
30
25
20
15
10
5
EQ
L-12/06Z
F-05/00Z
TCFA

TROPICAL STORM JEANA (31W)

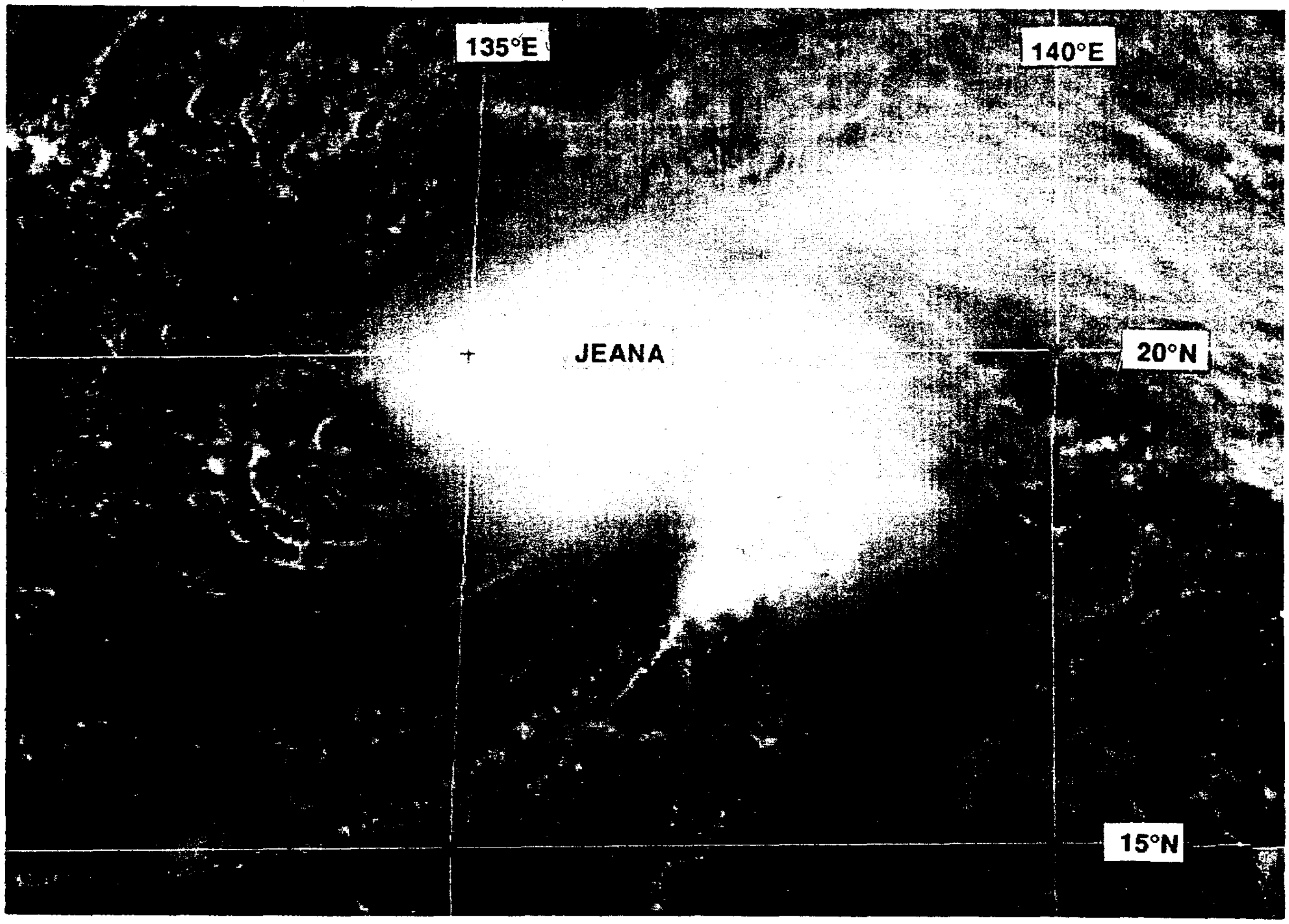


Figure 3-31-1 Still maintaining tropical storm intensity, Jeana begins to weaken as its low-level circulation becomes partially exposed (100531Z November visual GMS imagery).

I. HIGHLIGHTS

The first of four significant tropical cyclones to form during November, Tropical Storm Jeana reached its peak intensity at recurvature and dissipated (Figure 3-31-1). The NEXRAD Doppler radar was instrumental in tracking Jeana during its formative stages near and over Guam.

II. CHRONOLOGY OF EVENTS

November

022300Z - An area of persistent convection within the monsoon trough and near Kwajalein resulted in the first discussion of the disturbance in the Significant Tropical Weather Advisory.

041100Z - A Tropical Cyclone Formation Alert was issued after convection, consolidated near the circulation center.

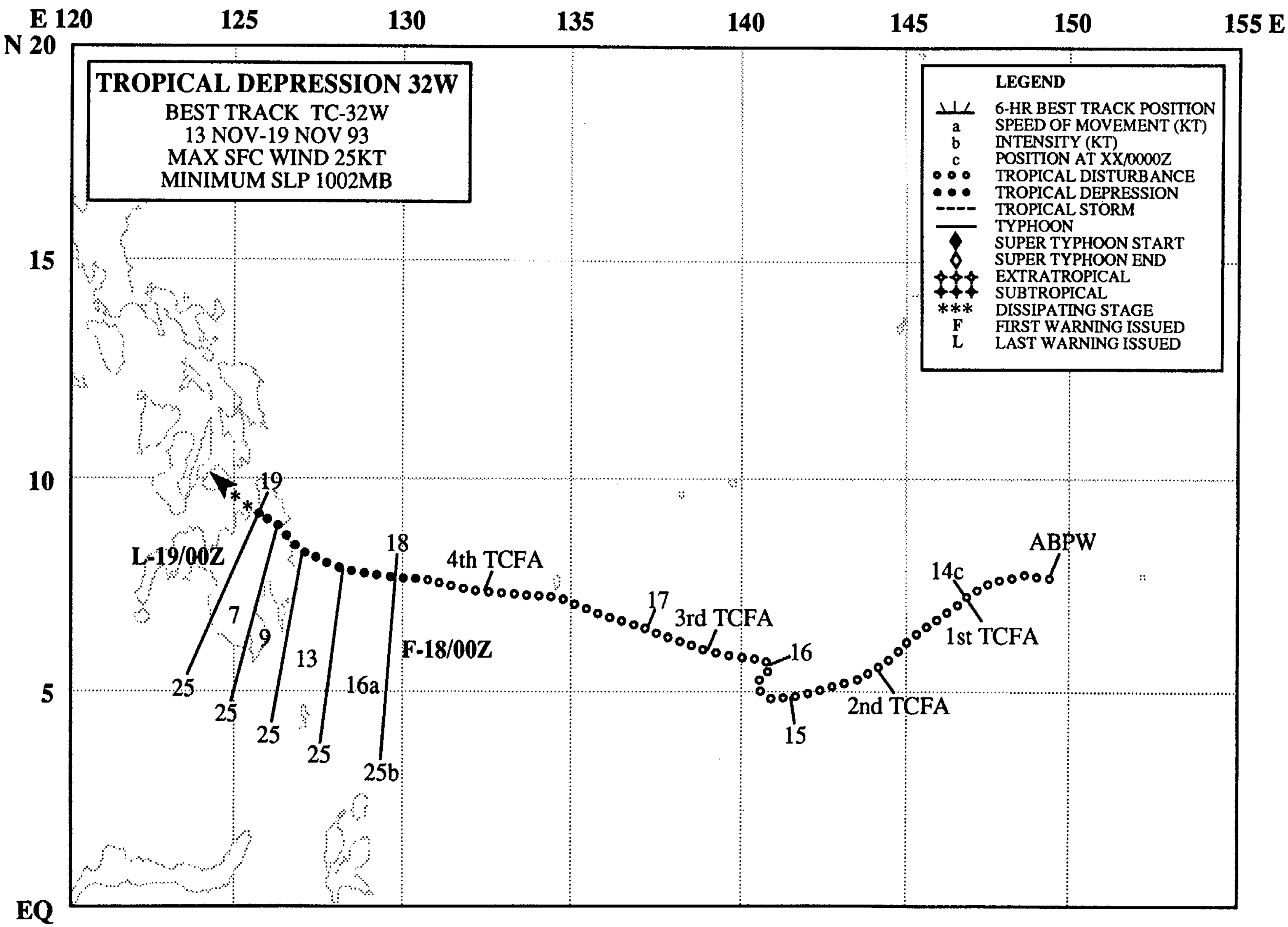
050000Z - The first warning was issued on Tropical Depression 31W based on increased convective curvature and the first daylight visual satellite imagery which indicated an intensity of 25 kt (13 m/sec

060000Z - Based on a satellite intensity estimate of 30 kt (15 m/sec) and the occurrence of intense con

vection near the circulation center, Jeana was upgraded to a tropical storm. Post-analysis of synoptic and satellite data indicates that Jeana more likely became a tropical storm at 081200Z.
120600Z - The final warning was issued on Jeana as it dissipated over water northwest of the Mariana Islands.

III. IMPACT

None.



TROPICAL DEPRESSION 32W
BEST TRACK TC-32W
13 NOV-19 NOV 93
MAX SFC WIND 25KT
MINIMUM SLP 1002MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 120
125
130
135
140
145
150
155 E
N 20
15
10
5
EQ
19
18
L-19/00Z
F-18/00Z
4th TCFA
3rd TCFA
2nd TCFA
1st TCFA
ABPW
14c
17
16
15
7
9
13
16a
25
25
25
25
25b

TROPICAL DEPRESSION 32W

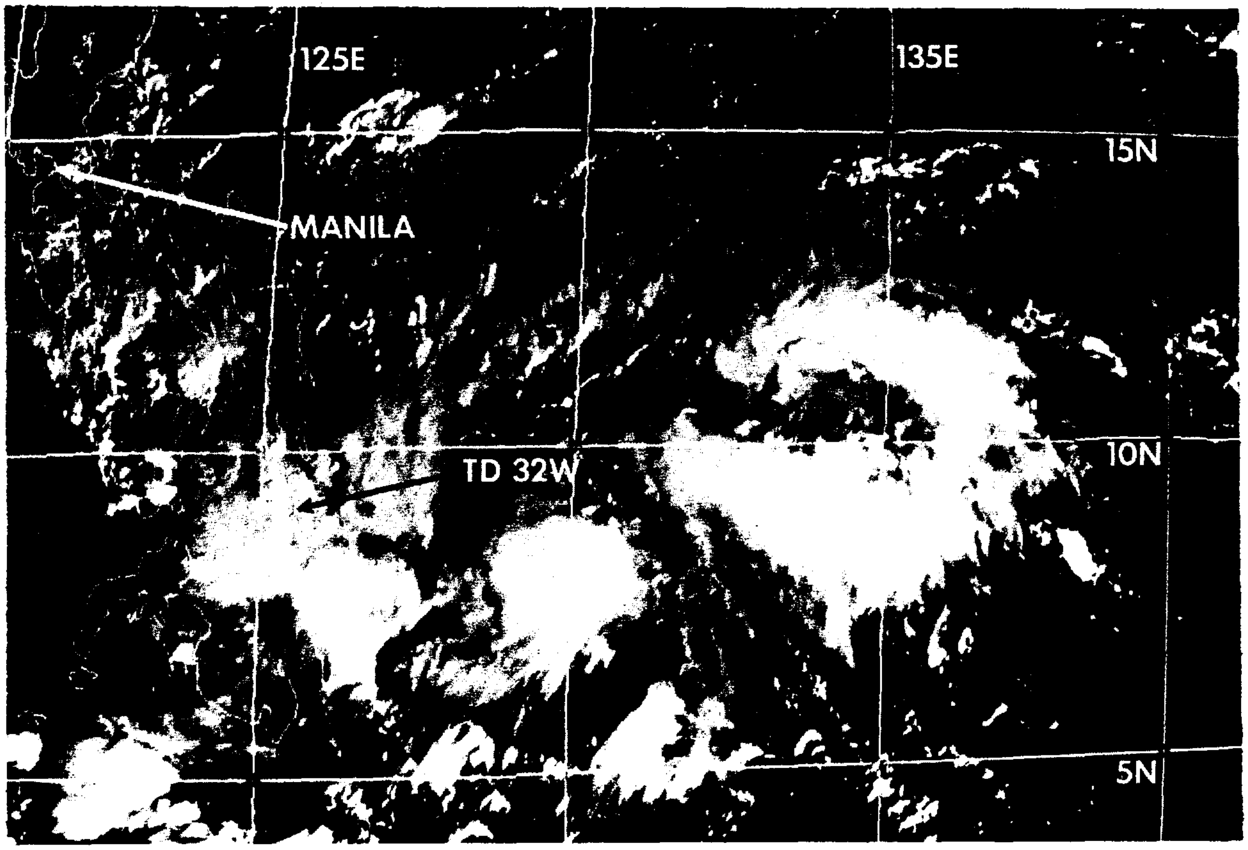


Figure 3-32-1 The remnants of TD 32W move into the southern Philippine Islands (182330Z November visual GMS imagery).

I. HIGHLIGHTS

Forming in the monsoon trough east of the international date line, Tropical Depression 32W was short-lived as a significant tropical cyclone despite going through a long consolidation stage. The weak, yet persistent disturbance required four Tropical Cyclone Formation Alerts before the first tropical depression warning was finally required.

II. CHRONOLOGY OF EVENTS

November

130600Z - An area of persistent convection within the monsoon trough resulted in the initial identification of the disturbance in the Significant Tropical Weather Advisory.

140000Z - A Tropical Cyclone Formation Alert (TCFA) was issued based on improved convective curvature and organization.

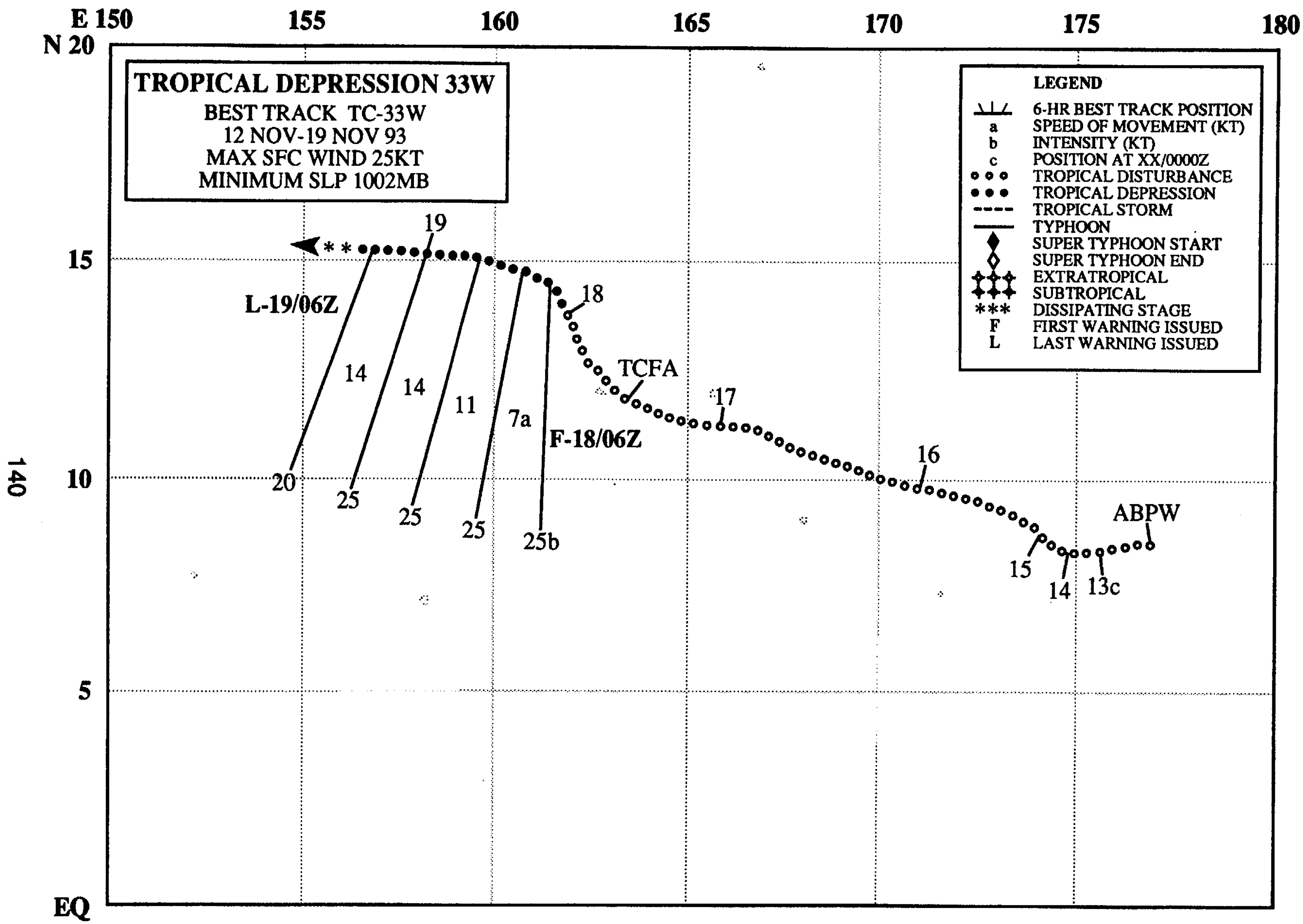
141400Z - The TCFA was reissued based upon a satellite position fix which indicated the system center had reorganizedto the south.

151400Z - The TCFA was canceled after all the deep convection associated with the circulation center had dissipated.

161630Z - A third TCFA was issued following a rapid increase in convective organization as the disturbance tracked westward towards the Philippines.
171630Z - The fourth TCFA was issued once the areal extent of convection increased and organization had slowly improved.
180000Z - The first warning was issued based on visible satellite imagery which indicated that the depression had a well-defined, although exposed, low level circulation center and an estimated intensity of 25 kt (13 m/sec).
190000Z - The final warning reflected the system's dissipation after its passage over Mindanao (Figure 3-32-1).

III. IMPACT

None.



TROPICAL DEPRESSION 33W
BEST TRACK TC-33W
12 NOV-19 NOV 93
MAX SFC WIND 25KT
MINIMUM SLP 1002MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 150
155
160
165
170
175
180
N 20
15
10
5
EQ
140
L-19/06Z
F-18/06Z
TCFA
ABPW
19
18
17
16
15
14
13c
14
14
11
7a
20
25
25
25
25b

TROPICAL DEPRESSION 33W

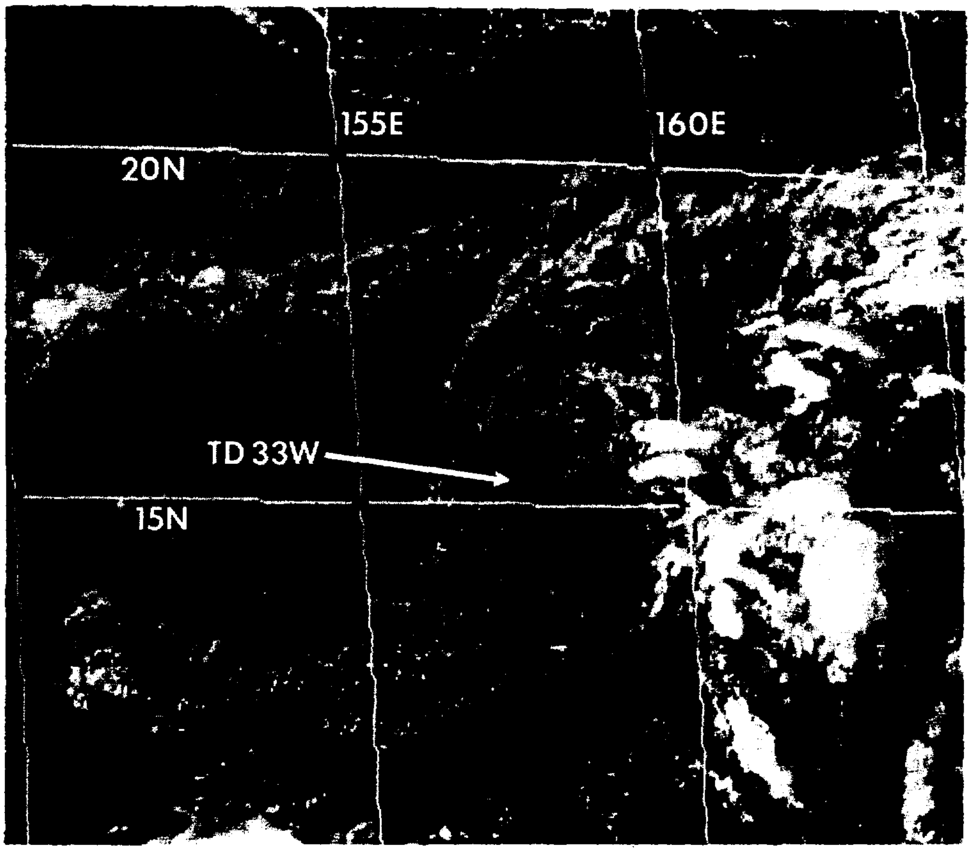


Figure 3-33-1 The only deep convection associated with TD 33W remains to the east of the exposed low-level circulation (182230Z November visual GMS imagery).

I. HIGHLIGHTS

The third tropical cyclone to form during November, Tropical Depression 33W (TD 33W) was another short-lived system which formed at nearly the same time as TD 32W. Development of depression was hampered by persistent vertical wind shear (Figure 3-33-1). TD 33W, was in warning status for only 18 hours.

II. CHRONOLOGY OF EVENTS

November

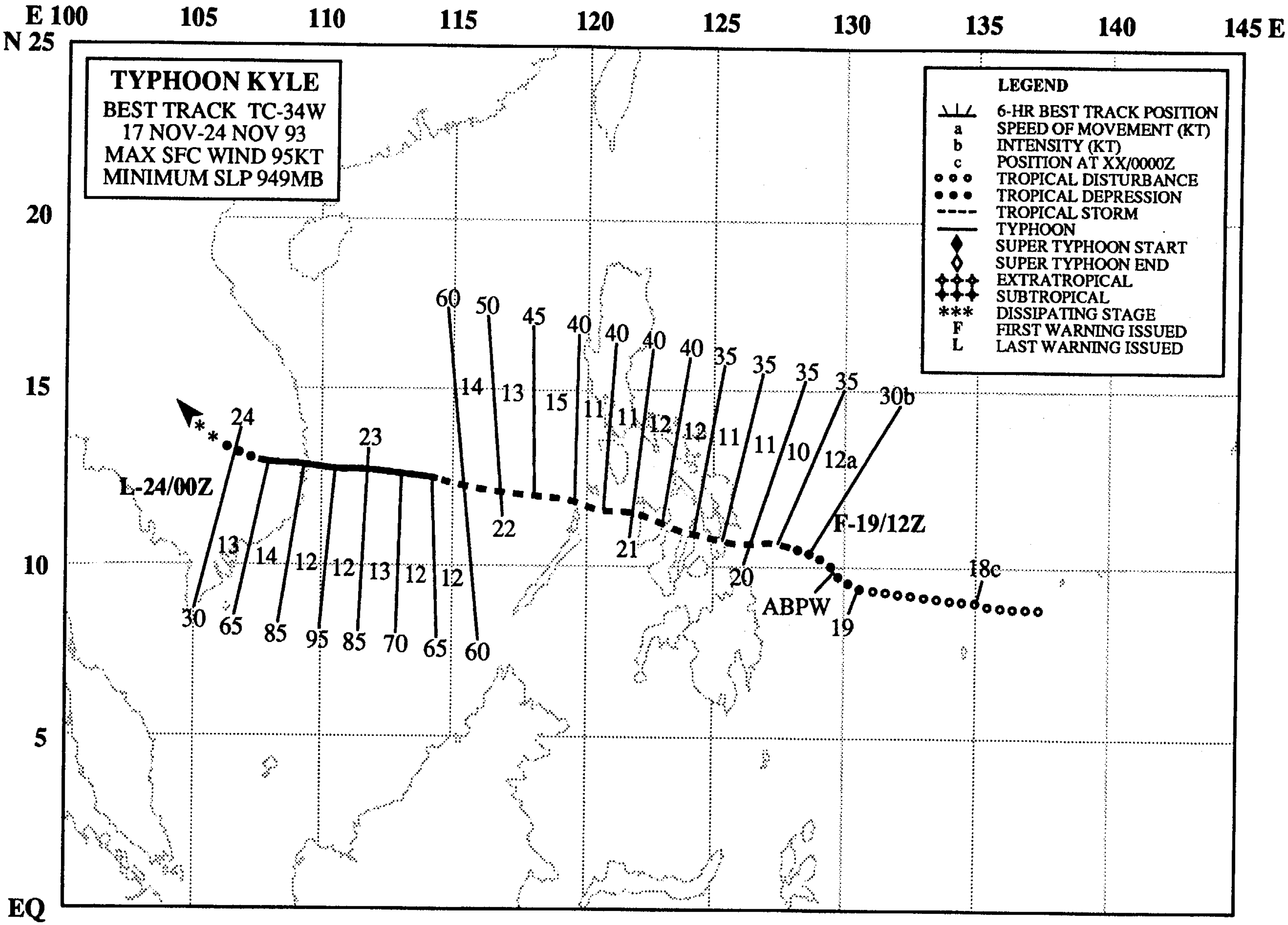
120600Z - An area of persistent convection within the monsoon trough andeast of Majuro in the Marshall Islands resulted in the first discussion of the disturbance in the Significant Tropical Weather Advisory.

171130Z - Issuance of a Tropical Cyclone Formation Alert was issued reflected the prescence of increased convective organization.

180600Z - The first warning was issued based on improved convective curvature and a satellite intensity estimate of 25 kt (13 m/sec).

190600Z - The final warning was issued on TD 33W as it dissipated over water.

III. IMPACT


TYPHOON KYLE
BEST TRACK TC-34W
17 NOV-24 NOV 93
MAX SFC WIND 95KT
MINIMUM SLP 949MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 100
105
110
115
120
125
130
135
140
145 E
N 25
20
15
10
5
EQ
L-24/00Z
F-19/12Z
ABPW
30b
12a
18c

TYPHOON KYLE (34W)

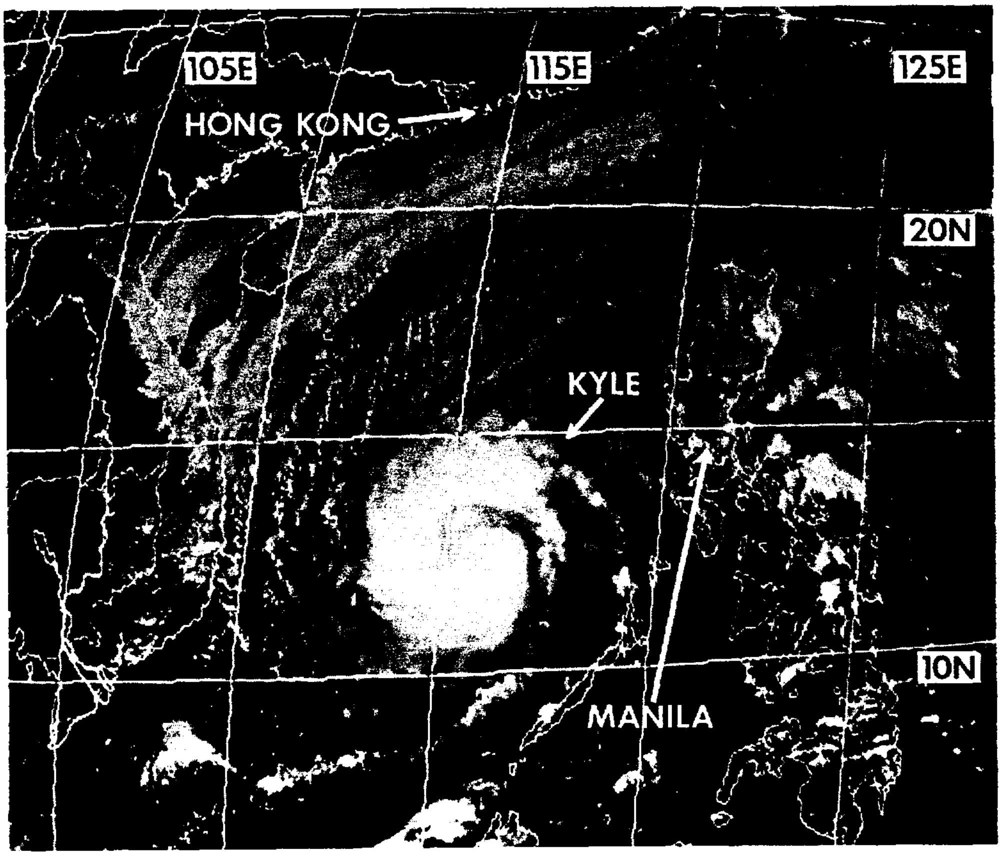


Figure 3-34-1 Over the warm waters of the South China Sea, Kyle rapidly approaches typhoon intensity (220530Z November visual GMS imagery).

I. HIGHLIGHTS

Initially developing from a monsoon depression, Typhoon Kyle was the only one of three significant tropical cyclones that formed during November to reach typhoon intensity. It developed rapidly near Palau, then slowly intensified while crossing the Philippines. Upon entering the South China Sea, Kyle quickly intensified (Figure 3-34-1) into a typhoon, and reached a peak intensity of 95 kt (49 m/sec) prior to landfall in central Vietnam.

II. CHRONOLOGY OF EVENTS

November

190600Z - An area of persistent convection associated with a monsoon depression resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.

191200Z - The first warning, based on a satellite intensity estimate of 30 kt (15 m/sec), was issued without a Tropical Cyclone Formation Alert in effect.

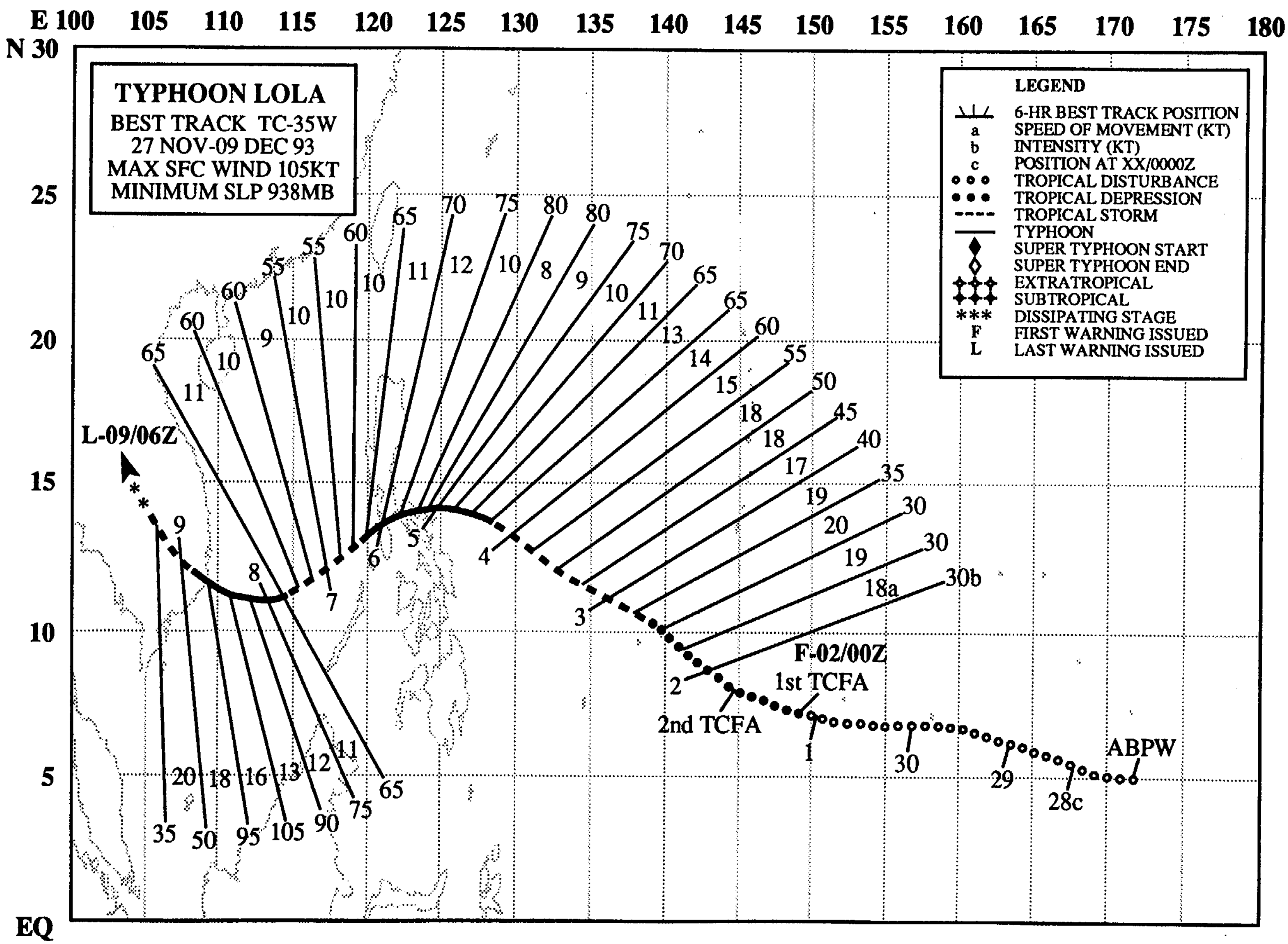
191800Z - The appearance of tighter convective curvature and a satellite intensity estimate of 35 kt (18 m/sec), led to Kyle's upgrad to a tropical storm.

221200Z - The development of an elongated eye and a satellite intensity estimate of 77 kt (40 m/sec), prompted forecasters to upgrade Kyle to a typhoon.

240000Z - The final warning was issued on Kyle as it was dissipating near the Cambodia-Thailand border.

III. IMPACT

News sources indicated that Kyle was responsible for 106 deaths occurred and 59 missing people in four southern Vietnamese provinces. In addition, damage to fisheries, agriculture, and infrastructure in Vietnam was estimated at (US)$1.5 million.



TYPHOON LOLA
BEST TRACK TC-35W
27 NOV-09 DEC 93
MAX SFC WIND 105KT
MINIMUM SLP 938MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 100
105
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
N 30
25
20
15
10
5
EQ
L-09/06Z
F-02/00Z
1st TCFA
2nd TCFA
ABPW
30b
18a
28c

TYPHOON LOLA (35W)

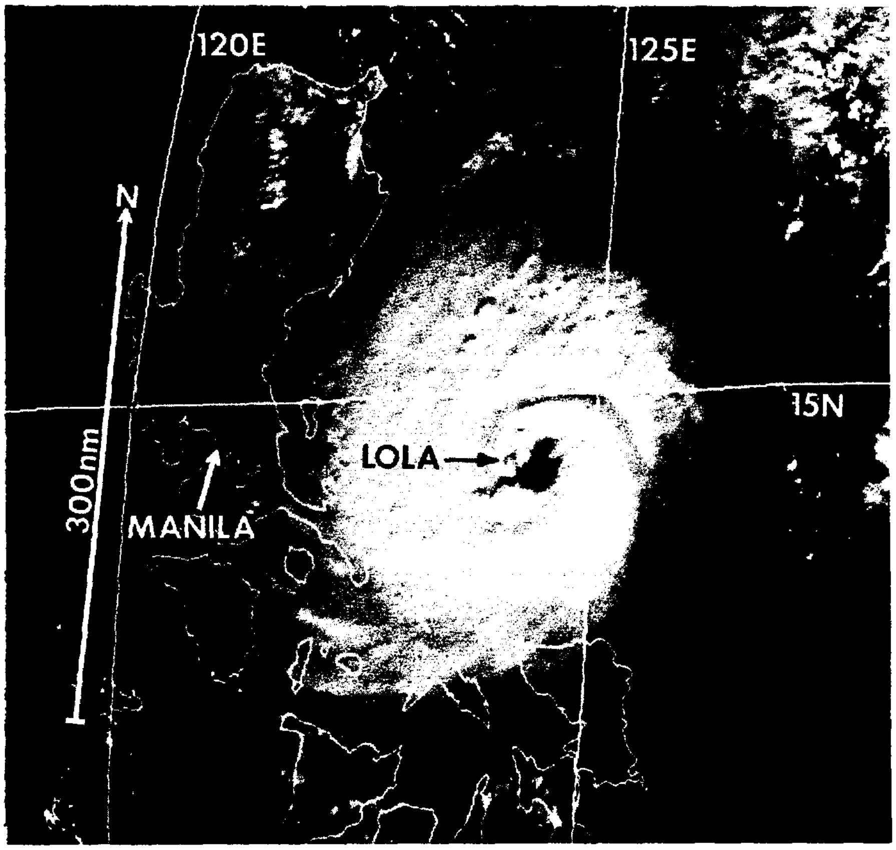


Figure 3-35-1 Lola with a 20 nm (35 km) diameter eye approaches southern Luzon (051230Z December visual GMS imagery.)

I. HIGHLIGHTS

Forming in an active near equatorial trough that ultimately produced three late-season typhoons, Lola slowly intensified to 80 kt (41 m/sec) before crossing the heavily populated Bicol region of southern Luzon (Figure 3-35-1). After killing hundreds of people and displacing more than half-a-million, the typhoon headed toward the southwest, tracing a sinusoidal path across the South China Sea. Lola rapidly reintensified over the South China Sea before moving over southern Vietnam.

II. CHRONOLOGY OF EVENTS

November

270600Z - An isolated area of persistent convection near the western Marshall Islands resulted in the first discussion of the disturbance in the Significant Tropical Weather Advisory.

December

010400Z - A TCFA was issued based on a consolidation of convection near the circulation center.

011900Z - A second TCFA was issued when the disturbance accelerated and moved out of the original TCFA area.

020000Z - The first warning was based on increased convective organization and a satellite intensity estimate of 30 kt (15 m/sec).

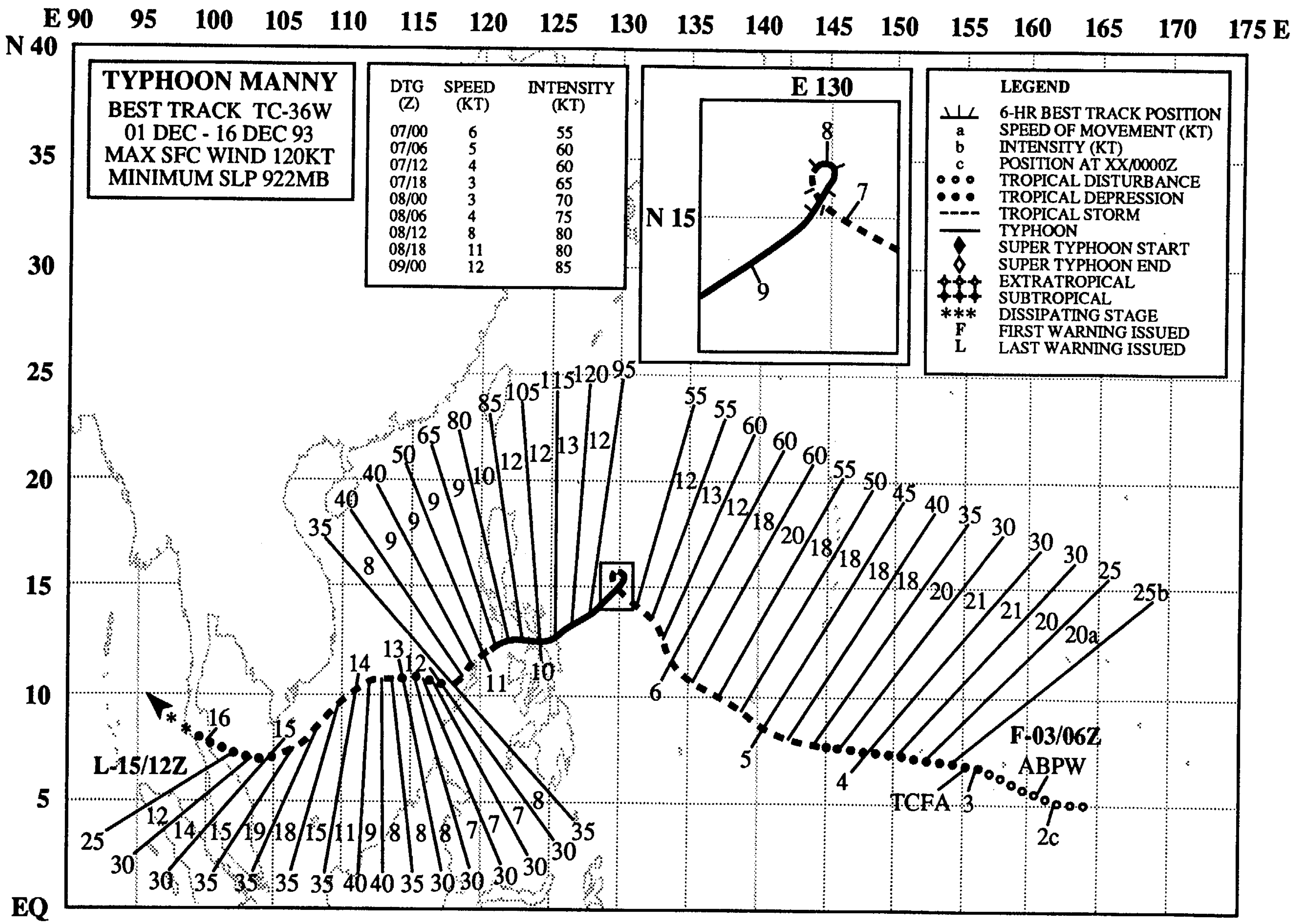
030000Z - As a result of a satellite intensity estimate of 45 kt (23 m/sec), Lola was upgraded to a tropi-

cal storm. Post analysis of synoptic and satellite data indicate that Lola probably attained tropical storm intensity at 021800Z.
040600Z - The appearance of an eye and a satellite intensity estimate of 65 kt (33 m/sec) led forecasters to upgrade Lola to a typhoon.
080000Z - After weakening over the Philippines and reintensifying in the South China Sea, Lola was upgraded to typhoon a second time based on a satellite intensity estimate of 65 kt (33 m/sec).
090600Z - The final warning for Lola was issued as it was rapidly dissipating over Vietnam.

III. IMPACT

In the Philippines, Lola killed over 230 people and forced more than 583,000 to flee their homes in the heavily populated Bicol region of southern Luzon near the city of Legazpi.

In southern Vietnam, the death toll was 78 with another 78 people reported missing. The region also suffered heavy agricultural losses with at least 40,000 acres of corn and 27,000 acres of rice destroyed.


TYPHOON MANNY
BEST TRACK TC-36W
01 DEC - 16 DEC 93
MAX SFC WIND 120KT
MINIMUM SLP 922MB
DTG (Z) | SPEED (KT) | INTENSITY (KT)
07/00 6 55
07/06 5 60
07/12 4 60
07/18 3 65
08/00 3 70
08/06 4 75
08/12 8 80
08/18 11 80
09/00 12 85
E 130
N 15
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
F-03/06Z
ABPW
TCFA
L-15/12Z
E 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 E
N 40 35 30 25 20 15 10 5 EQ

TYPHOON MANNY (36W)

I. HIGHLIGHTS

The second of three typhoons to form in a very active near equatorial trough in December, Manny developed in the eastern Caroline Islands. After moving rapidly westward into the Philippine Sea, the tropical cyclone slowed and executed a cyclonic loop before tracking southwestward towards the Philippine Islands. Rapid intensification occurred as Manny approached the Philippine Islands. Once in the South China Sea, Manny, influenced by shear from the Asian northeast monsoon, weakened and meandered west-southwestward until it dissipated over the Malay Peninsula. Typhoon Manny was the 19th significant tropical cyclone of 1993 to directly affect the Philippines, and followed a track almost identical to that of Typhoon Pamela in 1982.

II. CHRONOLOGY OF EVENTS

December

020600Z - Typhoon Manny was first mentioned in the Significant Tropical Weather Advisory as an area of persistent convection within the near equatorial trough east of Pohnpei in the Caroline Islands.

030300Z - Increased convective organization and regional 24-hour pressure falls of 2 to 2.5 mb led to the issuance of a Tropical Cyclone Formation Alert.

030600Z - The first warning on Manny resulted from the combination of improved convective curvature, a satellite intensity estimate of 25 kt (13 m/sec), and surface synoptic data from the Caroline Islands which indicated that a closed low-level circulation was present.

041800Z - Manny was upgraded to tropical storm intensity based on a satellite intensity estimate of 45 kt (23 m/sec). Post analysis indicates that Manny most likely attained tropical storm intensity almost six hours earlier.

080000Z - The appearance of an eye and a satellite intensity estimate of 65 kt (33 m/sec) to an upgrade to typhoon intensity.

151200Z - Final warning was issued on Manny as it was dissipating over the Malay Peninsula.

III. IMPACT

On Yap (WMO 91413), Manny produced sustained winds of 38 kt (20 m/sec) with gusts to 47 kt (24 m/sec), resulting in some minor damage to banana trees, but not to structures. The tropical storm dropped 6.45 inches (165 mm) of rain on the Island. During the early morning hours of 10 December in the Philippine Islands, the typhoon swept across Samar killing at least eight people. This was only 75 nm (139 km) south of where Typhoon Lola (35W) had passed a week earlier, killing at least 230 people and forcing 583,000 to flee their homes.

IV. DISCUSSION

There are two interesting aspects of Manny: its track in the Philippine Sea was virtually identical to that of another typhoon, Pamela (December 1982); and, its rapid intensification while on a southwesterly track.

a. Clockwise loop in the Philippine Sea — On 7 December, Manny (Figure 3-36-1) entered a clockwise loop that took two days to complete. While Manny's motion was unusual, it was not unprecedented, and, in fact, has a near-perfect analog. Figure 3-36-2 compares the track of Manny with that of Typhoon Pamela (1982). Both typhoons performed a clockwise loop approximately 100 nm (185 km)

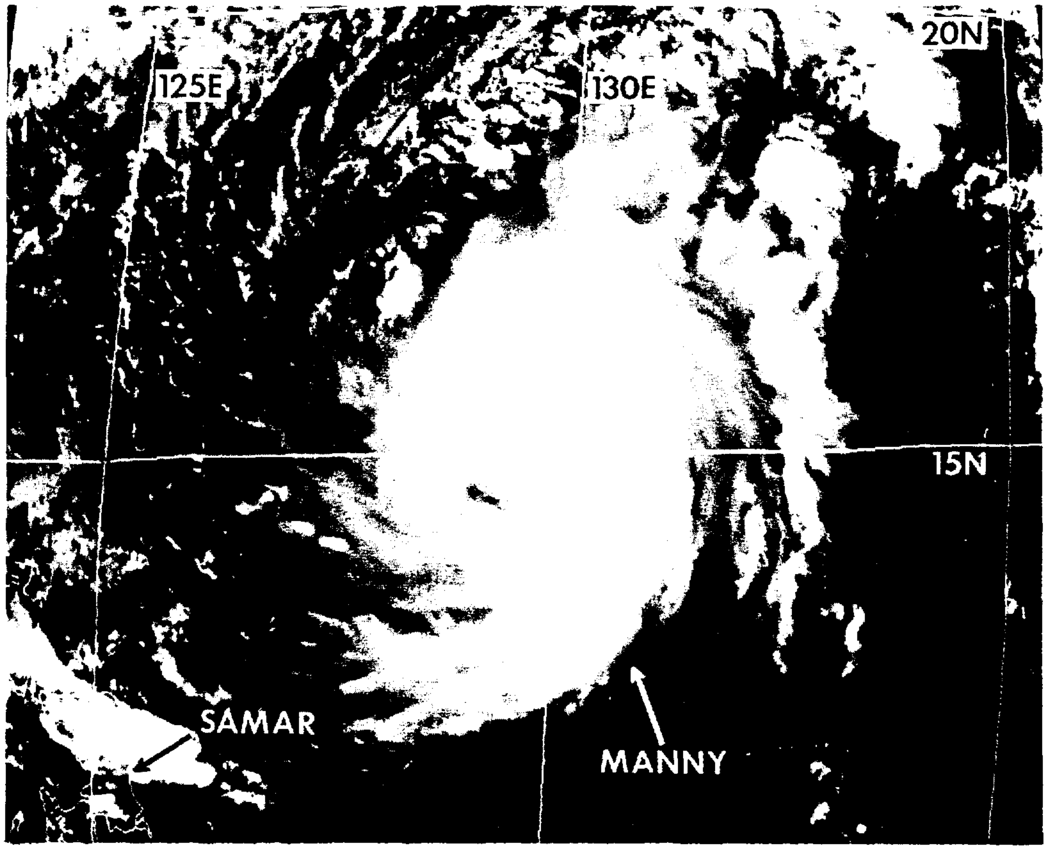


Figure 3-36-1 Approaching typhoon intensity, Manny begins to execute a clockwise loop in the Philippine Sea (070530Z December visual GMS imagery).

in diameter, tracked to the southwest and intensified.

b. Southwestward Track and Intensification — In tropical latitudes, tropical cyclones normally move in a direction north of west. Southwestward, tracks while not common, do occur with regularity. There are at least six distinct synoptic patterns that can cause a tropical cyclone to take a prolonged (24 hours or more) southwestward track. Four of these basic synoptic patterns are illustrated in Figure 3-36-3. The first synoptic pattern is the monsoon gyre (Figure 3-36-3a) described by Lander (1994). The second pattern, a surge in the northeast monsoon (Fig. 3-36-3b), occurs in the extreme western North Pacific and South China Sea from October through March. In this case, intensification is either short-lived or does not occur. The third pattern, induced ridging in low latitudes (Fig. 3-36-3c), may be associated with the reverse-oriented monsoon trough. The fourth pattern, dynamic ridging (Fig. 3-36-3d), is characterized by the subtropical ridge expanding. This expansion forces a tropical cylone to the southwest if the expansion is toward the southeast. Prior to the expansion a storm may respond to synoptic patterns that cause "stepping" and "looping" as identified by Sandgathe (1987). Although similar to the northeast monsoon pattern, tropical cyclones in the dynamic ridge pattern are less likely to weaken, and may even intensify significantly. The fifth and sixth synoptic patterns (not illustrated) are: southwestward motion associated with binary interaction, and tropical cyclones (usually TUTT-induced) that develop in the trade winds between the axes of the monsoon trough and the subtropical ridge. Of the six synoptic patterns, the dynamic ridge pattern (Figure 3-36-3d) applies to the movement of Manny while it was in the Philippine Sea.

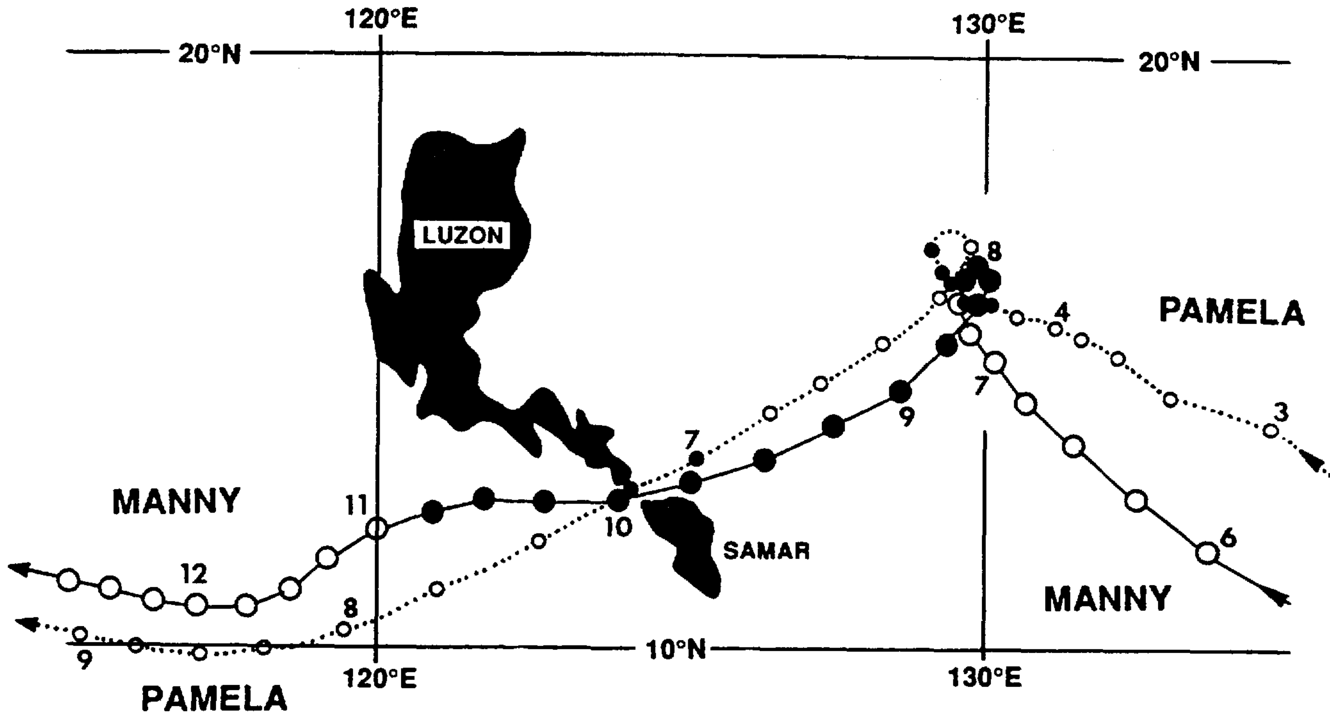


Figure 3-36-2 A comparison of the December tracks of Typhoons Manny (1993) and Pamela (1982). Both typhoons executed a clockwise loop in virtually the same location, and both intensified on their subsequent southwestward tracks. Manny's track is depicted by large circles connected by solid lines and Pamela's track is depicted by small circles connected with dotted lines. Tropical storm intensities are designated with open circles and typhoon intensities with filled circles. Dates at 0000Z are indicated by small numbers.

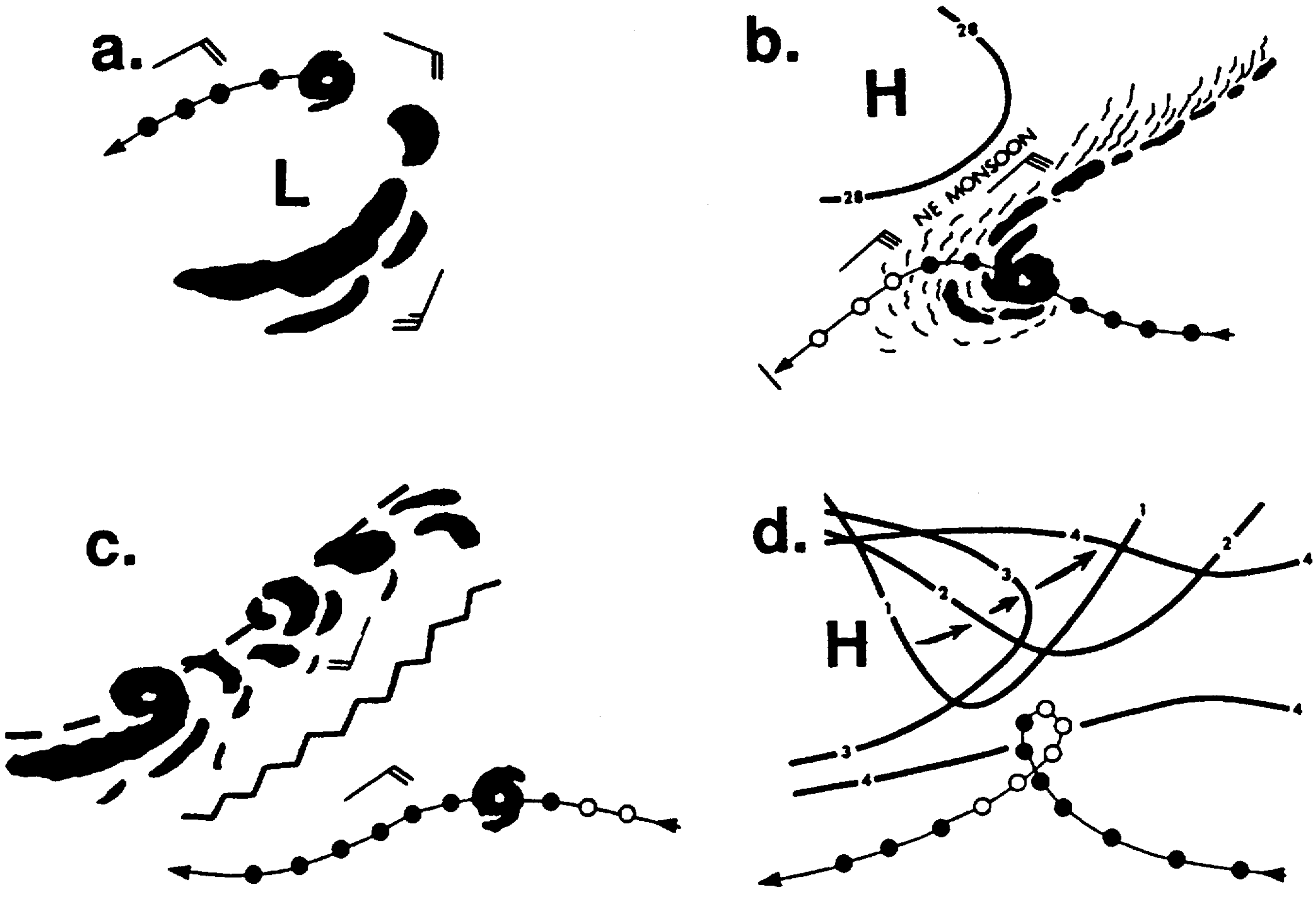
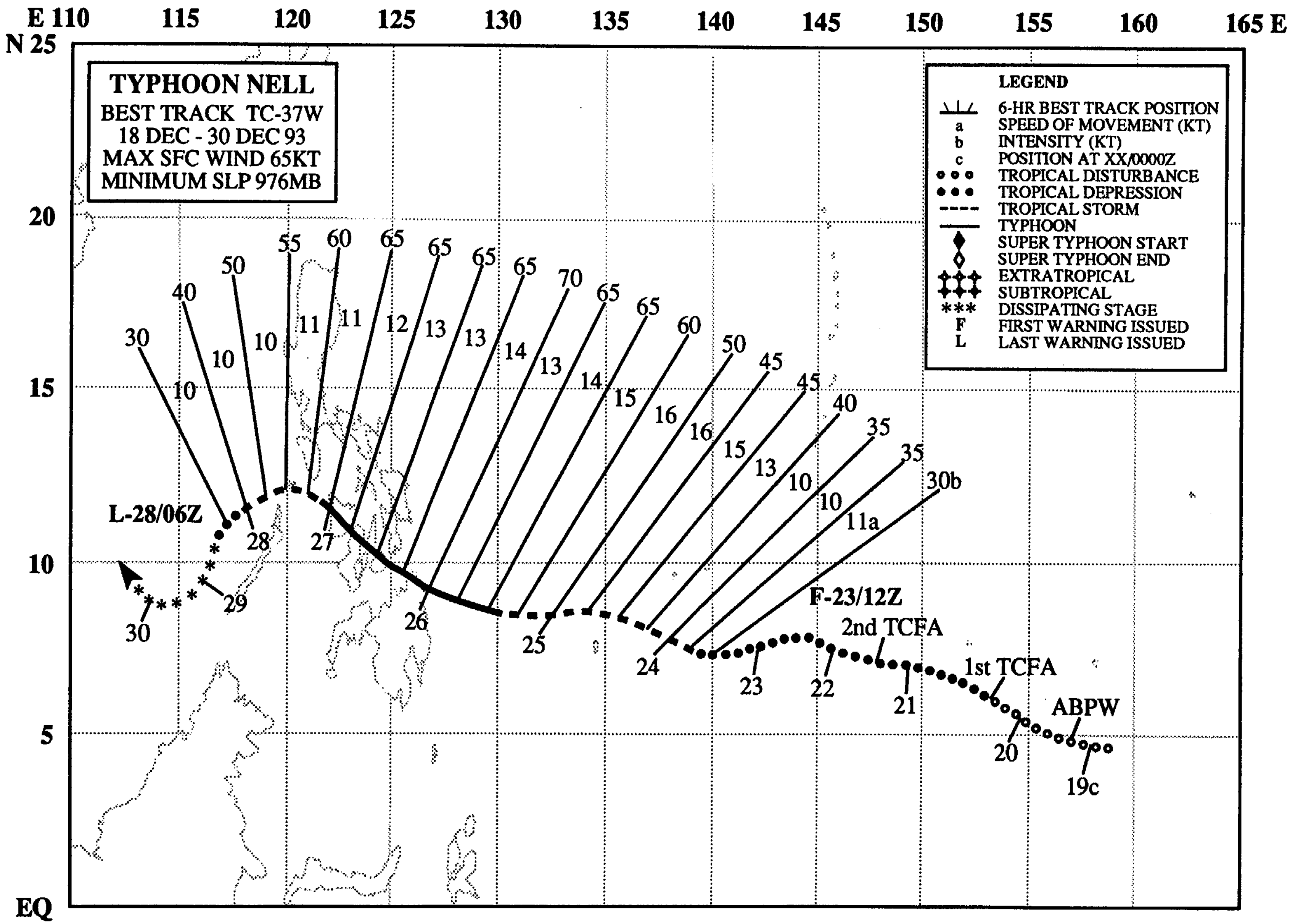


Figure 3-36-3 Primary synoptic patterns that cause tropical cyclones to move on a prolonged southwestward track: (a) Monsoon gyre, (b) northeast monsoon surge, (c) Induced ridging in low latitudes, and (d) dynamic ridging. Tropical cyclone track is depicted by circles connected by solid lines. Tropical storm intensities are designated by an open circle, typhoon intensities by filled circle. The 28 Isopleths in panel b means 1028 mb and numbers in panel d (1,2,3 and 4) indicate sequential daily movement.


TYPHOON NELL
BEST TRACK TC-37W
18 DEC - 30 DEC 93
MAX SFC WIND 65KT
MINIMUM SLP 976MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 110
115
120
125
130
135
140
145
150
155
160
165 E
N 25
20
15
10
5
EQ
L-28/06Z
F-23/12Z
2nd TCFA
1st TCFA
ABPW
30b
11a
19c

TYPHOON NELL (37W)

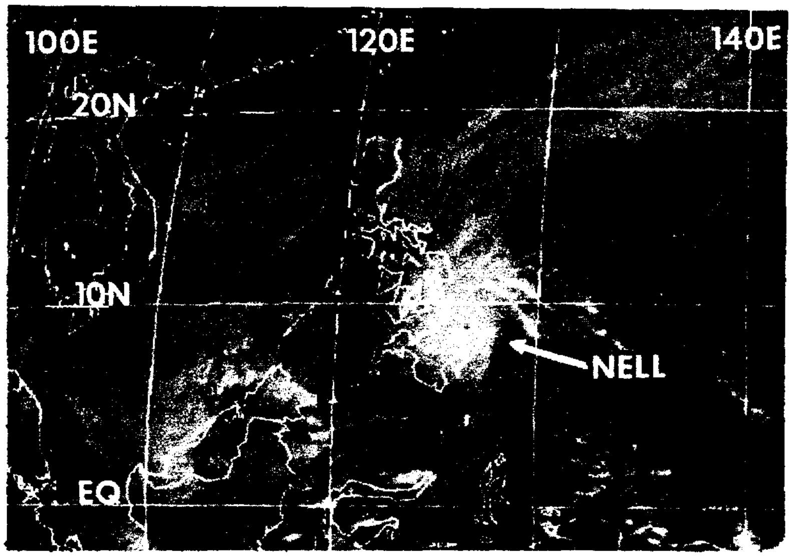


Figure 3-37-1 Typhoon Nell at peak intensity near Mindanao close to the time of landfall (260132Z December visual GMS imagery).

I. HIGHLIGHTS

The final tropical cyclone of the 1993 season, Typhoon Nell, developed south of Pohnpei in an active near equatorial trough. Embedded in a high vertical shear environment, Nell developed slowly while tracking westward through the Caroline Islands. Intensifying to typhoon strength before crossing the Philippines (Figure 3-37-1), Nell maintained typhoon intensity while crossing the islands. Once in the South China Sea, Nell entered a high vertical shear environment and quickly dissipated.

II. CHRONOLOGY OF EVENTS

December

190600Z - An area of persistent convection within the monsoon trough resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.
201300Z - A Tropical Cyclone Formation Alert (TCFA) was issued based on the development of deep convection near the circulation center and an overall improvement in organization.
211300Z - Although the disturbance did not intensify during the first TCFA, conditions remained favorable for development and a second TCFA was issued.
221300Z - The TCFA was canceled as the convection decreased steadily.
231200Z - The first warning was issued without a TCFA in effect, based on improved convective organization and a satellite intensity estimate of 25 kt (13 m/sec).
250000Z - A satellite intensity estimate of 35 kt (18 m/sec), led to the upgrade of Nell to a tropical storm. Post analysis indicates that Nell likely became a tropical storm over a day earlier, at 231800Z.
260000Z - Based on the first daylight satellite intensity estimate of 65 kt (33 m/sec), Nell was upgraded to a typhoon. Post analysis indicates that Nell actually achieved typhoon intensity about 12 hours earlier.
280600Z - The final warning was issued on Nell as it dissipated in the South China Sea in a high shear environment.

III. IMPACT

News agencies attributed seven deaths to Nell, six at Surigao City, Mindanao, near the area of landfall. Additionally, thousands of residents in low-lying river valleys in northern Mindanao were forced to evacuate to higher ground.

3.2 NORTH INDIAN OCEAN TROPICAL CYCLONES

Spring and fall in the North Indian Ocean are periods of transition between major climatic controls, and are the most favorable seasons for tropical cyclone activity. This year, only two significant tropical cyclones occurred, both in the fall transition month of November (Table 3-5). This amount of activity was unusually low for an ocean basin which typically experiences an average of five, and in sharp contrast to the previous year, 1992, which set a 18-year record high of 13 (Table 3-6). The last time only two tropical cyclones were recorded was 13 years earlier in 1980.

The best track composites for TC01A and TC02B are shown in Figure 3-14. Tropical Cyclone 01A formed in mid-November in conjunction with a twin, TC01S (Alexina), in the Southern Hemisphere. Later, at the end of the month, when the monsoon trough became active across the western North Pacific and Bay of Bengal, TC02B formed. During the first week of December, TC02B became part of a multiple storm outbreak along with Lola (35W) and Manny (36W).

Table 3-5 NORTH INDIAN OCEAN SIGNIFICANT TROPICAL CYCLONES FOR 1993

TROPICAL CYCLONE	PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/SEC)	ESTIMATED MSLP (MB)
TC 01A	12 NOV - 16 NOV	5	80 (41)	963
TC 02B	30 NOV - 05 DEC	6	75 (39)	967
	TOTAL	11		

The criteria used in Table 3-6 are as follows:

1. If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month.
2. If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.
3. If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

TABLE 3-6 LEGEND

Total for the month/year → 2

Typhoons → 2 0 0

Tropical Storms

Tropical Depressions

Table 3-6 DISTRIBUTION OF NORTH INDIAN OCEAN TROPICAL CYCLONES FOR 1975-1993

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1975	1	0	0	0	2	0	0	0	0	1	2	0	6
	010	000	000	000	200	000	000	000	000	100	020	000	3 3 0
1976	0	0	0	1	0	1	0	0	1	1	0	1	5
	000	000	000	010	000	010	000	000	010	010	000	010	0 5 0
1977	0	0	0	0	1	1	0	0	0	1	0	2	5
	000	000	000	000	010	010	000	000	000	010	000	110	1 4 0
1978	0	0	0	0	1	0	0	0	0	1	2	0	4
	000	000	000	000	000	000	000	000	000	010	200	000	2 2 0
1979	0	0	0	0	1	1	0	0	2	1	2	0	7
	000	000	000	000	100	010	000	000	011	010	011	000	1 4 2
1980	0	0	0	0	0	0	0	0	0	0	1	1	2
	000	000	000	000	000	000	000	000	000	000	010	010	0 2 0
1981	0	0	0	0	0	0	0	0	1	0	1	1	3
	000	000	000	000	000	000	000	000	010	000	100	100	2 1 0
1982	0	0	0	0	1	1	0	0	0	2	1	0	5
	000	000	000	000	100	010	000	000	000	020	100	000	2 3 0
1983	0	0	0	0	0	0	0	1	0	1	1	0	3
	000	000	000	000	000	000	000	010	000	010	010	000	0 3 0
1984	0	0	0	0	1	0	0	0	0	1	2	0	4
	000	000	000	000	010	000	000	000	000	010	200	000	2 2 0
1985	0	0	0	0	2	0	0	0	0	2	1	1	6
	000	000	000	000	020	000	000	000	000	020	010	010	0 6 0
1986	1	0	0	0	0	0	0	0	0	0	2	0	3
	010	000	000	000	000	000	000	000	000	000	020	000	0 3 0
1987	0	1	0	0	0	2	0	0	0	2	1	2	8
	000	010	000	000	000	020	000	000	000	020	010	020	0 8 0
1988	0	0	0	0	0	1	0	0	0	1	2	1	5
	000	000	000	000	000	010	000	000	000	010	110	010	1 4 0
1989	0	0	0	0	1	1	0	0	0	0	1	0	3
	000	000	000	000	010	010	000	000	000	000	100	000	1 2 0
1990	0	0	0	1	1	0	0	0	0	0	1	1	4
	000	000	000	001	100	000	000	000	000	000	001	010	1 1 2
1991	1	0	0	1	0	1	0	0	0	0	1	0	4
	010	000	000	100	000	010	000	000	000	000	010	000	1 3 0
1992	0	0	0	0	1	2	1	0	1	3	3	2	13
	000	000	000	000	100	020	010	000	001	021	210	020	3 8 2
1993	0	0	0	0	0	0	0	0	0	0	2	0	2
	000	000	000	000	000	000	000	000	000	000	200	000	2 0 0
(1975-1993)													
AVERAGE	0.2	0.1	0.0	0.2	0.6	0.6	0.1	0.1	0.3	0.9	1.5	0.5	4.8
CASES	3	1	0	3	12	11	1	1	5	17	28	10	92

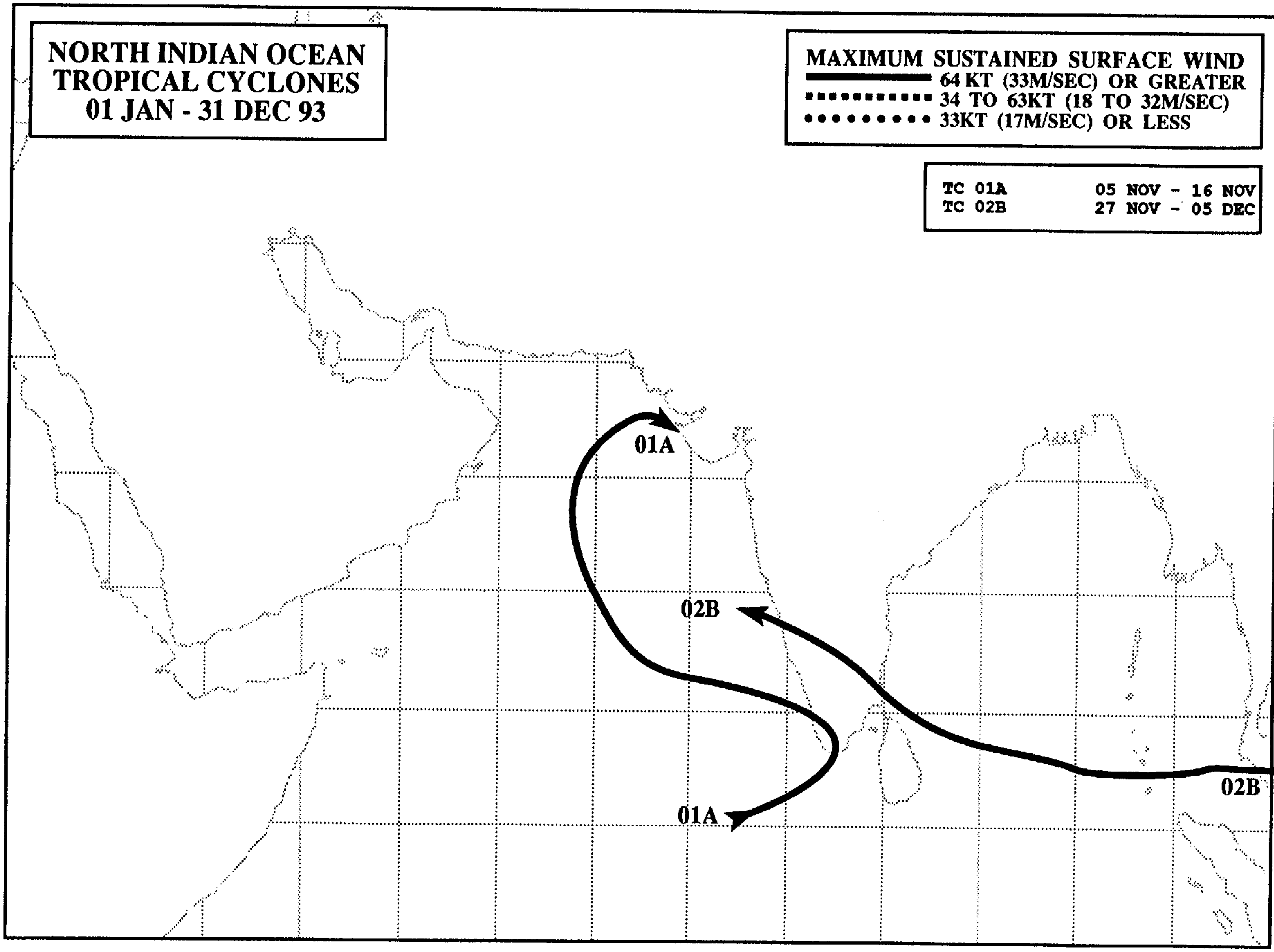
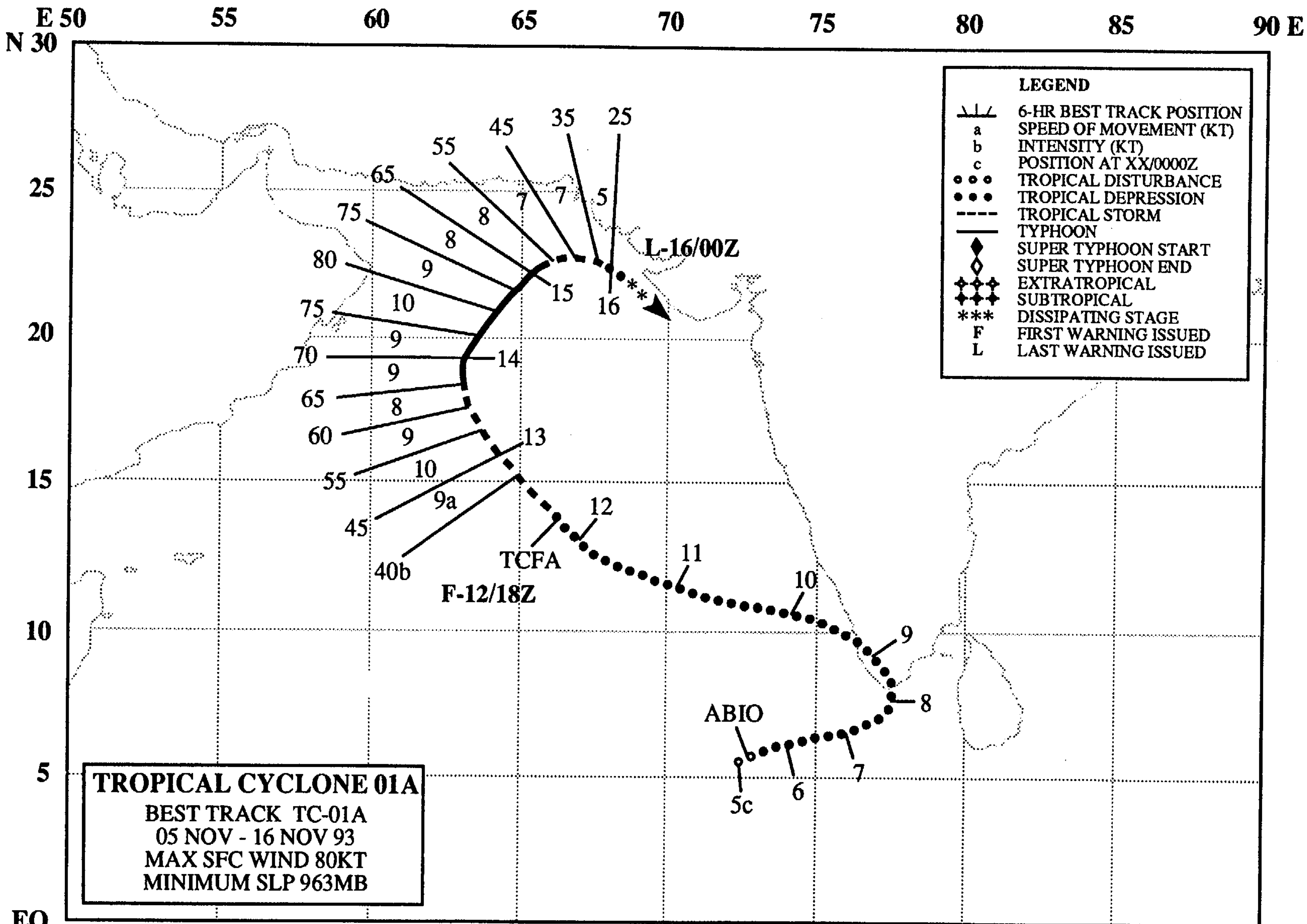


Figure 3-14 Composite best track for the North Indian Ocean tropical cyclones for 1993.



E 50
55
60
65
70
75
80
85
90 E
N 30
25
20
15
10
5
EQ
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-16/00Z
F-12/18Z
TCFA
ABIO
5c
6
7
8
9
10
11
12
13
14
15
16
40b
45
9a
55
10
60
9
65
8
70
9
75
9
80
10
75
9
65
8
55
8
45
7
35
7
25
5
TROPICAL CYCLONE 01A
BEST TRACK TC-01A
05 NOV - 16 NOV 93
MAX SFC WIND 80KT
MINIMUM SLP 963MB

TROPICAL CYCLONE 01A

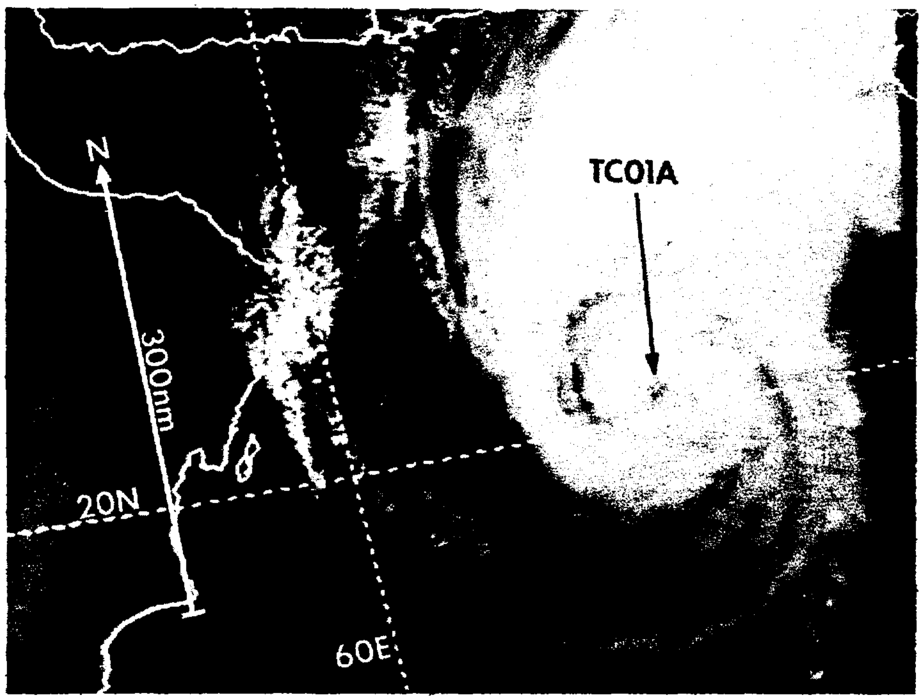


Figure 3-01A-1 TC 01A in the central Arabian Sea is within 12 hours of reaching its peak intensity of 80 kt (41 m/sec) (140059Z November visible DMSP image).

I. HIGHLIGHTS

The only significant tropical cyclone to occur in the Arabian Sea during 1993, Tropical Cyclone 01A (TC 01A), originated southwest of India. After persisting for a week, TC 01A entered a low shear environment and steadily intensified to 80 kt (41 m/sec) (Figure 3-01A-1). Following recurvature to the northeast and attainment of peak intensity on 14 November, the tropical cyclone entered a region of high vertical shear near the Pakistan-India border and dissipated over water.

II. CHRONOLOGY OF EVENTS

November

050600Z - An area of persistent convection caused JTWC to mention the disturbance in the Significant Tropical Weather Advisory.

120600Z - A TCFA was issued on the developing disturbance based on an increase in convection near the low-level circulation center.

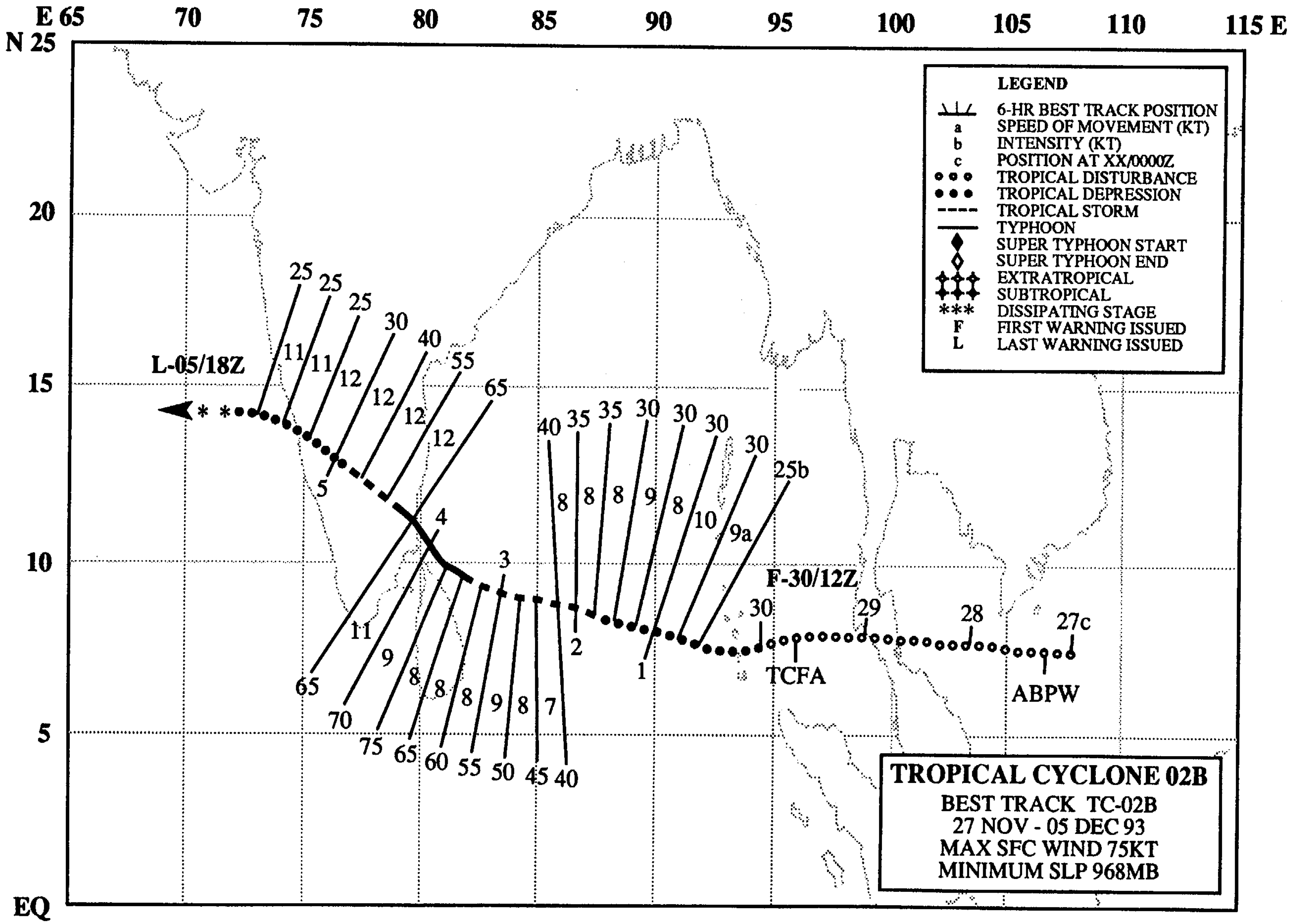
121800Z - The first warning was issued on TC 01A based on a satellite intensity estimate of 35 kt (18 m/sec).

131800Z - Based upon a satellite intensity estimate of 65 kt (33 m/sec) led forecasters to upgrade TC 01A to typhoon intensity.

160000Z - The final warning was issued on TC 01A as the system dissipated over water.

III. IMPACT

No reports received.


E 65
70
75
80
85
90
95
100
105
110
115 E
N 25
20
15
10
5
EQ
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-05/18Z
F-30/12Z
TCFA
ABPW
25b
9a
27c
TROPICAL CYCLONE 02B
BEST TRACK TC-02B
27 NOV - 05 DEC 93
MAX SFC WIND 75KT
MINIMUM SLP 968MB

TROPICAL CYCLONE 02B

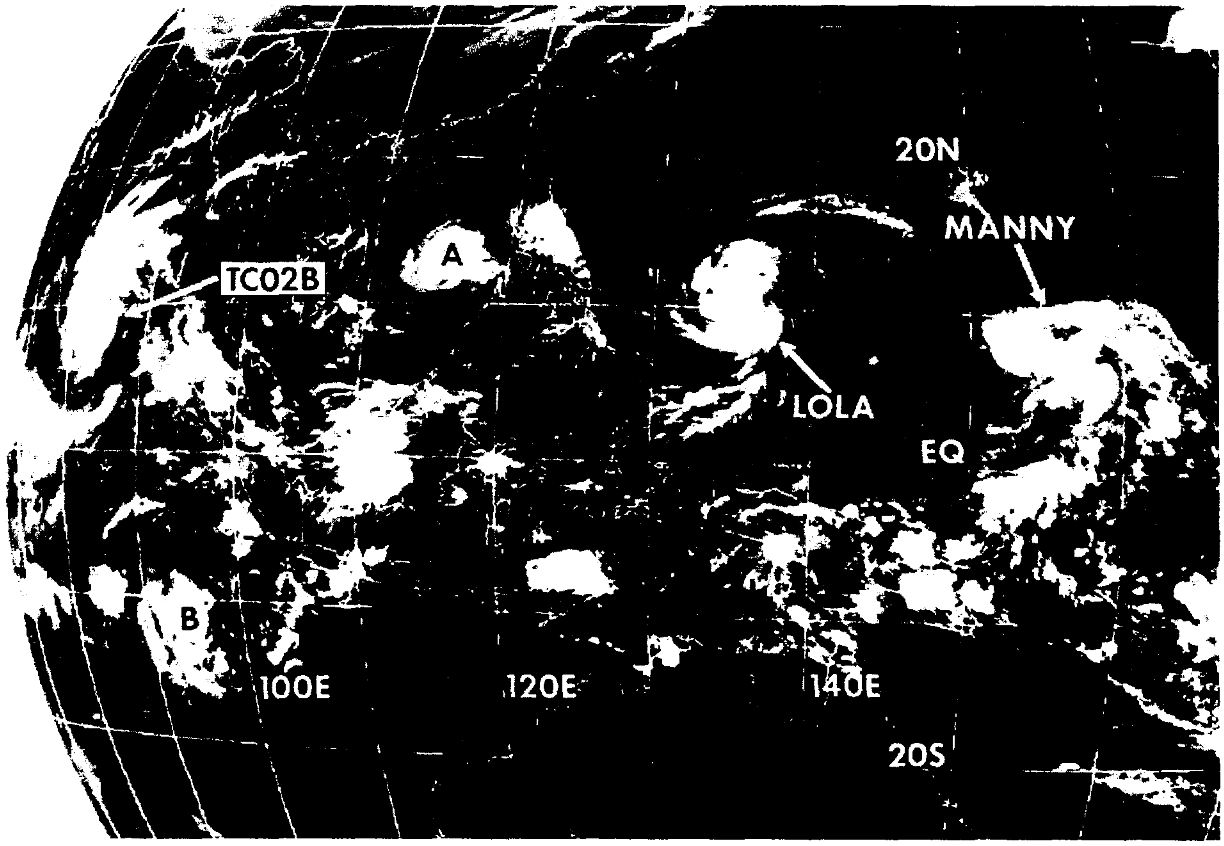


Figure 3-02B-1 TC 02B is part of a multiple storm outbreak that includes: Lola (35W) and Manny (36W) in the western North Pacific, and two tropical disturbances, (A) and (B), in the South China Sea and South Indian Ocean, respectively.

I. HIGHLIGHTS

The only significant tropical cyclone to affect the Bay of Bengal during 1993, Tropical Cyclone 02B (TC 02B), originated in the South China Sea. After passing over the Malay Peninsula, TC 02B tracked westward towards Sri Lanka and southern India while steadily intensifying. Before TC 02B passed over southern India and dissipated just off shore in the Arabian Sea, it became part of a multiple storm outbreak (Figure 3-02B-1).

II. CHRONOLOGY OF EVENTS

November

270600Z - An area of persistent convection, south of Vietnam, resulted in the first mention of the disturbance in the Significant Tropical Weather Advisory.

291630Z - A Tropical Cyclone Formation Alert was issued based on an increase in convection and synoptic data which indicated a weak surface cyclonic circulation.

301200Z - The first warning was issued based on a satellite intensity estimate of 25 kt (13 m/sec).

December

031200Z - Based on a satellite intensity estimate of 65 kt (33 m/sec), TC 02B was upgraded to typhoon intensity.

051800Z - The final warning was issued after TC 02B traversed southern India, entered the Arabian Sea, and dissipated.

III. IMPACT

None.

Captions:

Figure 3-01A-1 TC 01A in the central Arabian Sea is within 12 hours of reaching its peak intensity of 80 kt (41 m/sec) (140059Z November visible DMSP image).

Intentionally left blank.

4. SUMMARY OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES

4.1 GENERAL

On 1 October 1980, JTWC's area of responsibility (AOR) was expanded to include the Southern Hemisphere from 180° east longitude, westward to the coast of Africa. Details on Southern Hemisphere tropical cyclones and JTWC warnings from July 1980 through June 1982 are contained in Diercks et al. (1982) and from July 1982 through June 1984, in Wirfel and Sandgathe (1986). Information on Southern Hemisphere tropical cyclones after June 1984 can be found in the applicable Annual Tropical Cyclone Report.

The NAVPACMETOCCEN, Pearl Harbor, Hawaii issues warnings on tropical cyclones in the South Pacific, east of 180° east longitude. In accordance with CINCPACINST 3140.1V, Southern Hemisphere tropical cyclones are numbered sequentially from 1 July through 30 June. This convention is established to encompass the Southern Hemisphere tropical cyclone season, which primarily occurs from January through April. There are two Southern Hemisphere ocean basins for warning purposes - the South Indian (west of 135° east longitude) and the South Pacific (east of 135° east longitude) - which are identified by appending the suffixes "S" and "P," respectively, to the tropical cyclone number.

Intensity estimates for Southern Hemisphere tropical cyclones are derived from the interpretation of satellite imagery using the Dvorak (1984) technique and, in rare instances, from surface observations. The Dvorak technique relates specific cloud signatures to maximum sustained one-minute average surface wind speeds. The conversion from maximum sustained winds to minimum sea-level pressure is obtained from Atkinson and Holliday (1977) (Table 4-1).

4.2 SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES

The total number of significant tropical cyclones during the 1993 season (1 July 1992 - 30 June 1993) (Table 4-2) was 27 which matched the overall climatological mean for the past 13 years as shown in Table 4-3. However, looking at the annual variation of Southern Hemisphere Tropical Cyclones by ocean basins (Table 4-4), it becomes apparent that this mean value of 27 occurred with lower than normal activity in the South Pacific and South Indian

Table 4-1 MAXIMUM SUSTAINED 1-MINUTE MEAN SURFACE WINDS AND EQUIVALENT MINIMUM SEA-LEVEL PRESSURE (ATKINSON AND HOLLIDAY, 1977) RELATIONSHIP

WIND-KT	(M/SEC)	PRESSURE (MB)
30	(15)	1000
35	(18)	997
40	(21)	994
45	(23)	991
50	(26)	987
55	(28)	984
60	(31)	980
65	(33)	976
70	(36)	972
75	(39)	967
80	(41)	963
85	(44)	958
90	(46)	954
95	(49)	948
100	(51)	943
105	(54)	938
110	(57)	933
115	(59)	927
120	(62)	922
125	(64)	916
130	(67)	910
135	(69)	906
140	(72)	898
145	(75)	892
150	(77)	885
155	(80)	879
160	(82)	872
165	(85)	865
170	(87)	858
175	(90)	851
180	(93)	844

Ocean basins and higher than normal activity in the Australian basin. The above-average activity in the Australian basin tied the 13-year record high of 16 established in 1986. By comparison, the occurrence of only one tropical cyclone in the South Pacific tied the 13-year record low set in 1991 for that basin.

The JTWC was in warning status a total of 102 days, which included 25 days when the JTWC issued warnings on two or more Southern Hemisphere tropical cyclones, and seven days with three. There were no days with four or more occurring simultaneously. A chronology is provided in Figure 4-1. All tropical cyclone warnings with the exception of those for Tropical Cyclones 04S, 13S (Lena), 18P (Nisha) and 26S (Konita) were preceded by Tropical Cyclone Formation Alerts. With regard to tropical cyclones with estimated maximum surface winds of 130 kt (67 m/sec) or greater, 1993 was the first year since 1987 without any in the Southern Hemisphere. Composites of the best tracks appear in Figures 4-2 and 4-3.

Table 4-2 SOUTH PACIFIC AND SOUTH INDIAN OCEAN SIGNIFICANT TROPICAL CYCLONES, 1993 SEASON (1 JULY 1992-30 JUNE 1993)

TROPICAL CYCLONE	PERIOD OF WARNING	WARNINGS ISSUED	MAX SURFACE WINDS-KT (M/SEC)	ESTIMATED MSLP (MB)
01S Aviona	27 Sep - 01 Oct	8	65(33)	976
02S Babie	18 Oct - 21 Oct	6	45(23)	991
03P Joni	06 Dec - 12 Dec	17	110(57)	933
04S ----	07 Dec - 10 Dec	12	35(18)	997
05S Ken	19 Dec - 23 Dec	9	45(23)	991
06P Nina	23 Dec - 04 Jan	28	75(39)	967
07P Kina	26 Dec - 04 Jan	23	120(62)	922
08P ----*	02 Jan - 03 Jan	3*	45(23)	991
09P ----*	11 Jan - 13 Jan	5*	30(15)	1000
10S Colina	14 Jan - 21 Jan	14	95(49)	948
11S Dessilia	20 Jan - 21 Jan	2	35(18)	997
12S Edwina	20 Jan - 29 Jan	19	110(57)	933
13S Lena	24 Jan - 29 Jan	11	55(28)	984
14P ----*	26-28 Jan/06-07 Feb	8*	35(18)	997
15P Lin*	31 Jan - 04 Feb	9*	90(46)	954
16P Oliver	04 Feb - 12 Feb	17	115(59)	927
17P Mick*	05 Feb - 09 Feb	8*	45(23)	991
18P Nisha*	12 Feb - 16 Feb	10*	65(33)	976
19S Finella	13 Feb - 15 Feb	6	75(39)	967
20P Oli	16 Feb - 18 Feb	4	50(26)	987
21P Polly	25 Feb - 03 Mar	14	100(51)	943
22P Roger	12 Mar - 18 Mar	13	55(28)	984
23P Prema	27 Mar - 01 Apr	14	125(64)	916
24S Jourdanne	03 Apr - 09 Apr	14	125(64)	916
25S Monty	10 Apr - 12 Apr	4	50(26)	987
26S Konita	02 May - 07 May	13	90(46)	954
27P Adel	13 May - 16 May	7	45(23)	991
	JTWC Total	263		
		35*		
	Grand Total	298		

* Warnings issued by NAVPACMETOCCEN

NOTE: Names of Southern Hemisphere tropical cyclones are assigned by the appropriate sub-regional Tropical Cyclone Advisory Center (Madagascar and Mauritius) or Tropical Cyclone Warning Center (Australia (Perth, Darwin and Brisbane), Fiji and Papua New Guinea).

Table 4-3 MONTHLY DISTRIBUTION OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES

YEAR	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTAL
(1959-1978) AVERAGE*	-	-	-	0.4	1.5	3.6	6.1	5.8	4.7	2.1	0.5	-	24.7
1981	0	0	0	1	3	2	6	5	3	3	1	0	24
1982	1	0	0	1	1	3	9	4	2	3	1	0	25
1983	1	0	0	1	1	3	5	6	3	5	0	0	25
1984	1	0	0	1	2	5	5	10	4	2	0	0	30
1985	0	0	0	0	1	7	9	9	6	3	0	0	35
1986	0	0	1	0	1	1	9	9	6	4	2	0	33
1987	0	1	0	0	1	3	6	8	3	4	1	1	28
1988	0	0	0	0	2	3	5	5	3	1	2	0	21
1989	0	0	0	0	2	1	5	8	6	4	2	0	28
1990	2	0	1	1	2	2	4	4	10	2	1	0	29
1991	0	0	1	1	1	3	2	5	5	2	1	1	22
1992	0	0	1	1	2	5	4	11	3	2	1	0	30
1993	0	0	1	1	0	5	7	7	2	2	2	0	27
TOTAL	5	1	5	8	19	43	76	91	56	37	14	2	357
(1981-1993) AVERAGE	0.4	0.1	0.4	0.6	1.6	3.3	5.8	7.0	4.3	2.8	1.1	0.2	27.5

* (Gray, 1979)

Table 4-4 ANNUAL VARIATION OF SOUTHERN HEMISPHERE TROPICAL CYCLONES BY OCEAN BASIN

YEAR	SOUTH INDIAN (WEST OF 105°E)	AUSTRALIAN (105°E - 165°E)	SOUTH PACIFIC (EAST OF 165°E)	TOTAL
(1959-1978) AVERAGE*	8.4	10.3	5.9	24.7
1981	13	8	3	24
1982	12	11	2	25
1983	7	6	12	25
1984	14	14	2	30
1985	14	15	6	35
1986	14	16	3	33
1987	9	8	11	28
1988	14	2	5	21
1989	12	9	7	28
1990	18	8	3	29
1991	11	10	1	22
1992	11	6	13	30
1993	10	16	1	27
TOTAL	159	129	69	357
(1981-1993) AVERAGE	12.2	9.9	5.3	27.5

* (Gray, 1979)

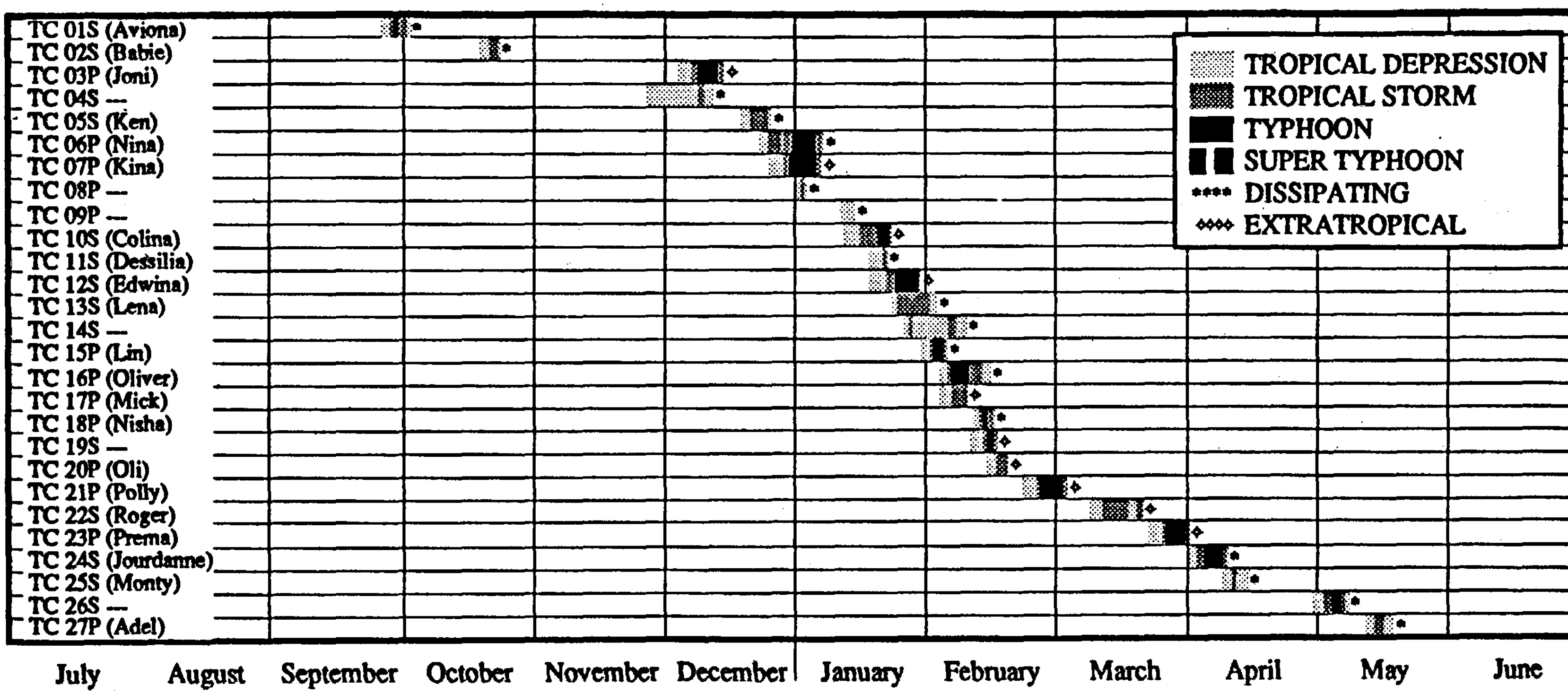


Figure 4-1 Chronology of South Pacific and South Indian Ocean tropical cyclones for 1993 (1 July 1992 - 30 June 1993)

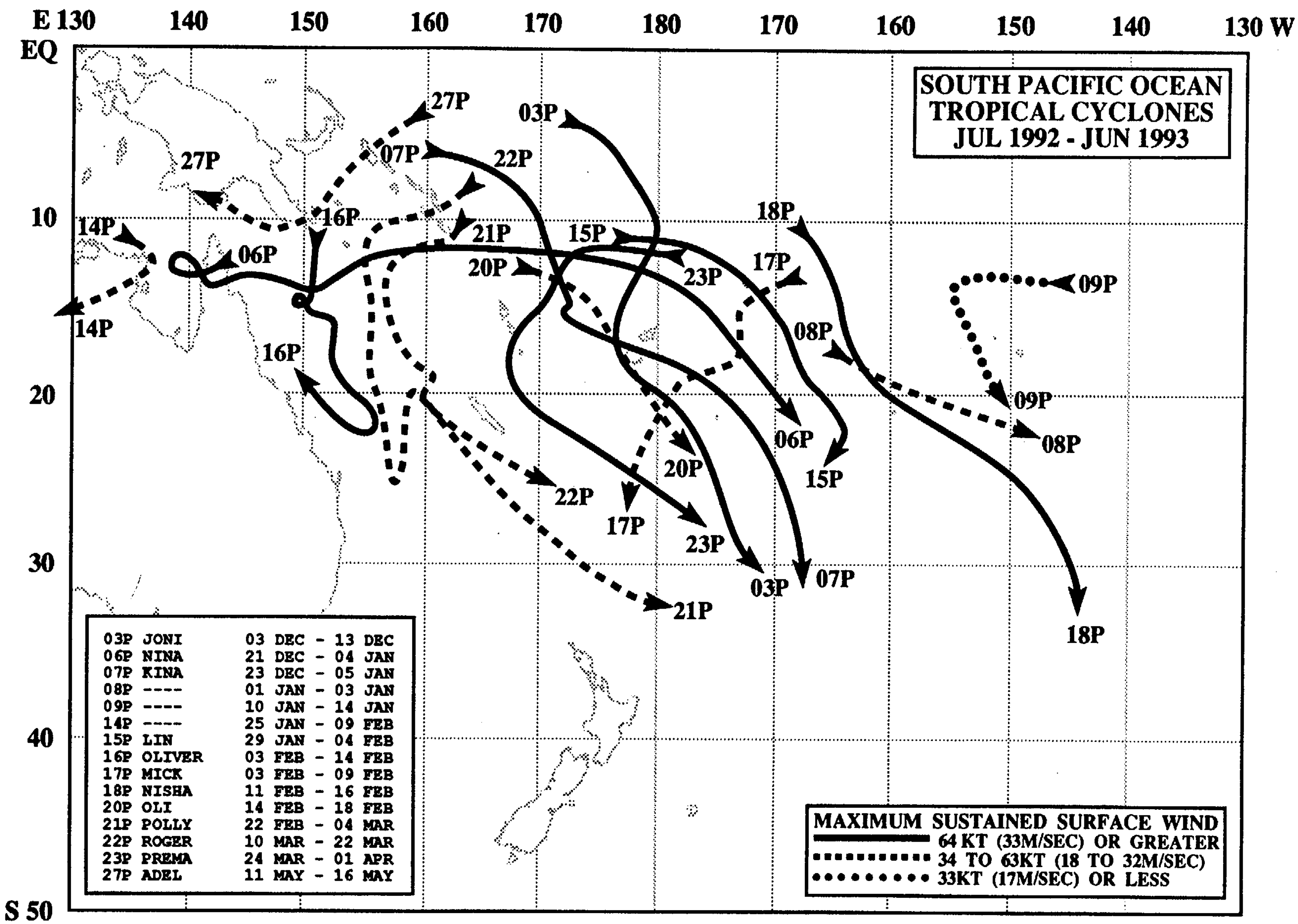


Figure 4-2 Tropical cyclone best tracks east of 130° east longitude

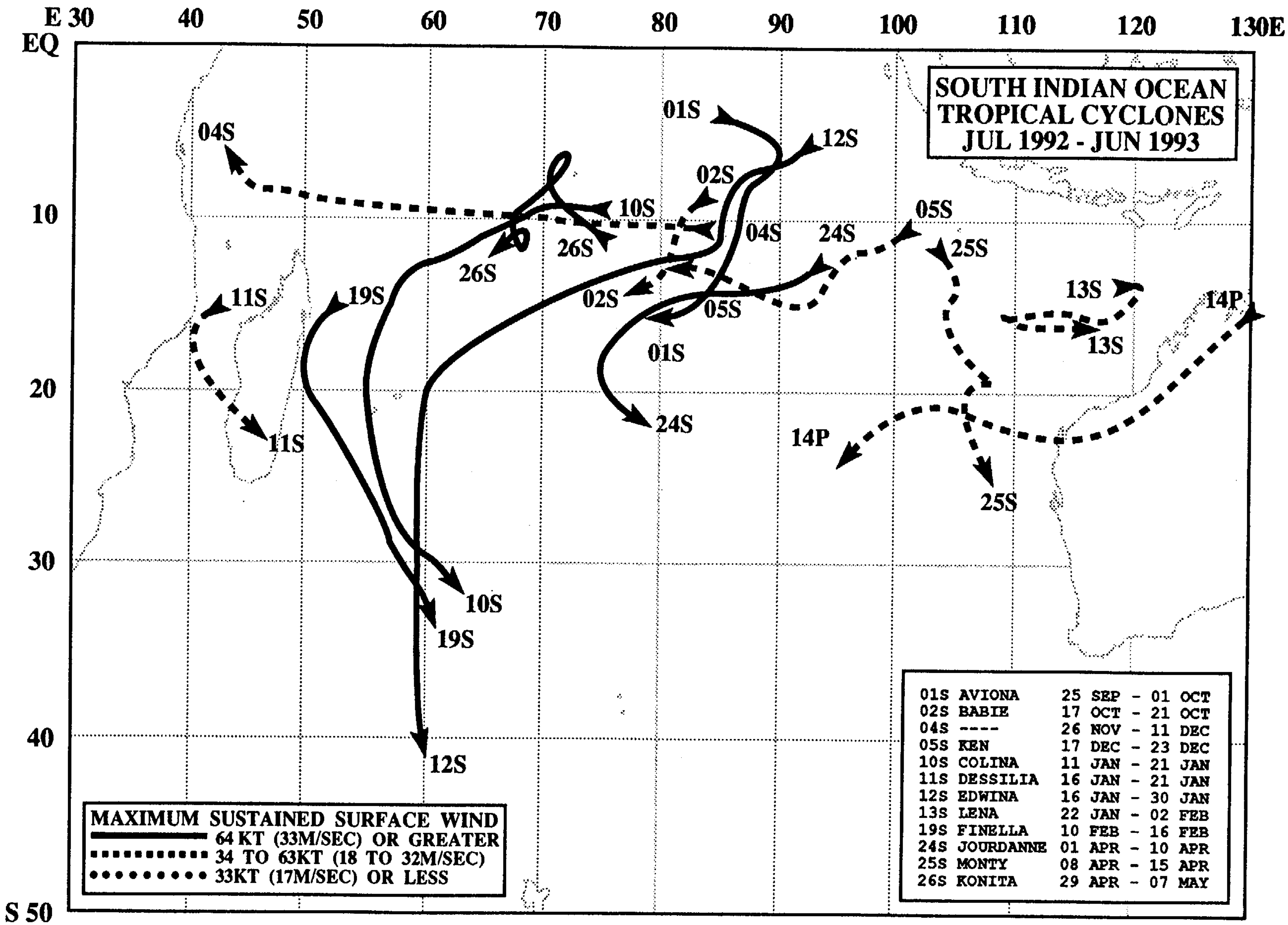


Figure 4-3 Tropical cyclone best tracks west of 130° east longitude

5. SUMMARY OF FORECAST VERIFICATION

5.1 ANNUAL FORECAST VERIFICATION

Verification of warning positions and intensities at initial, 24-, 48- and 72-hour forecast periods was made against the final best track. The (scalar) track forecast, along-track and cross-track errors (illustrated in Figure 5-1) were calculated for each verifying JTWC forecast. These data, in addition to a detailed summary for each tropical cyclone, are included as Chapter 6. This section summarizes verification data for 1993 and contrasts it with annual verification statistics from previous years.

5.1.1 NORTHWEST PACIFIC OCEAN — The frequency distributions of errors for initial warning positions and 12-, 24-, 36-, 48- and 72-hour forecasts are presented in Figures 5-2a through 5-2f, respectively. Table 5-1 includes mean track, along-track and cross-track errors for 1978-1993. Figure 5-3 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours for the past 20 years. Table 5-2 lists annual mean track errors from 1959, when the JTWC was founded, until the present. Figure 5-4 illustrates JTWC intensity forecast errors at 24-, 48- and 72-hours for the past 20 years.

5.1.2 NORTH INDIAN OCEAN — The frequency distributions of errors for warning positions and 12-, 24-, 36-, 48- and 72-hour forecasts are presented in Figures 5-5a through 5-5f, respectively. Table 5-3 includes mean track, along-track and cross-track errors for 1978-1993. Figure 5-6 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours for the 20 years that the JTWC has issued warnings in the region.

5.1.3 SOUTH PACIFIC AND SOUTH INDIAN OCEANS — The frequency distributions of errors for warning positions and 12-, 24-, 36-, and 48-hour forecasts are presented in Figures 5-7a through 5-7e, respectively. Table 5-4 includes mean track, along-track and cross-track errors for 1981-1993. Figure 5-8 shows mean track errors and a 5-year running mean of track errors at 24- and 48-hours for the 13 years that the JTWC has issued warnings in the region.

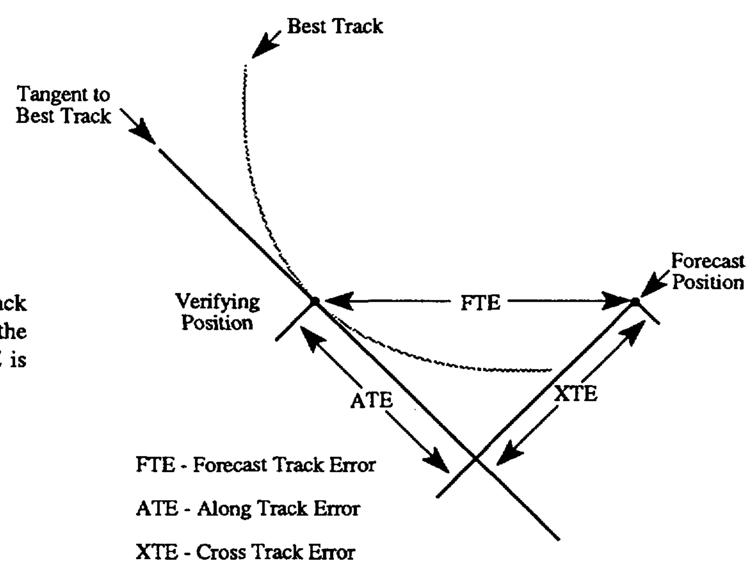


Figure 5-1 Definition of cross-track error (XTE), along-track error (ATE) and forecast track error (FTE). In this example, the XTE is positive (to the right of the best track) and the ATE is negative (behind or slower than the best track).

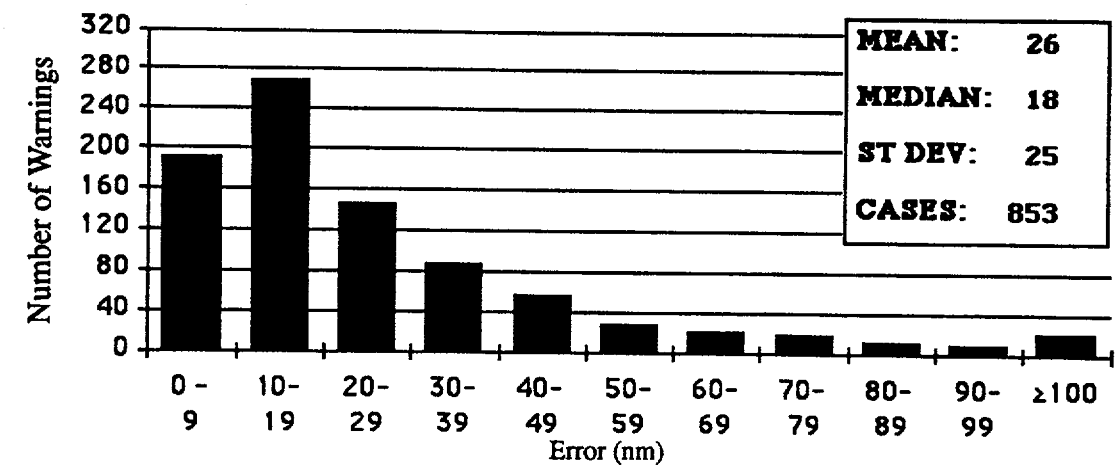


Figure 5-2a Frequency distribution of initial warning position errors (10-nm increments) for the western North Pacific Ocean in 1993. The largest error, 160 nm, occurred on Tropical Storm Marian (09W).

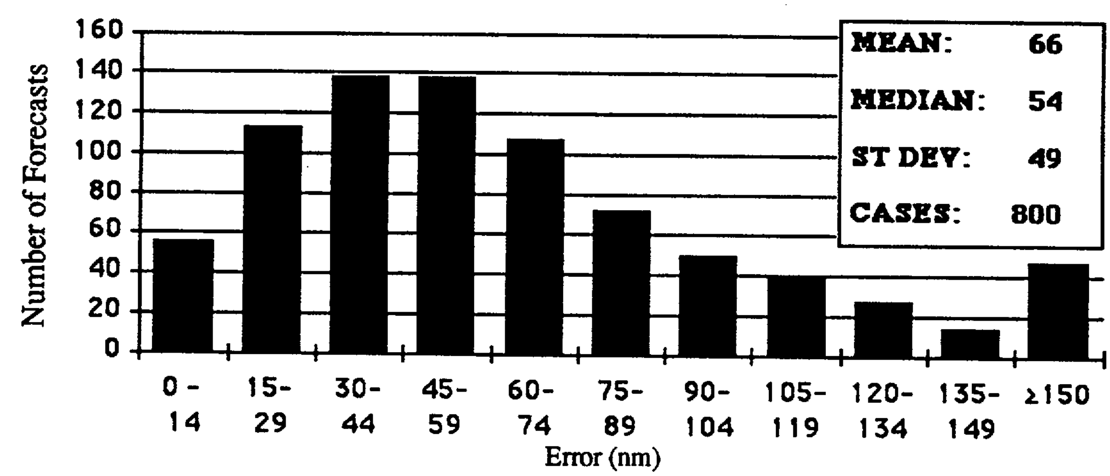


Figure 5-2b Frequency distribution of 12-hour forecast errors (15-nm increments) for the western North Pacific Ocean in 1993. The largest error, 427 nm, occurred on Super Typhoon Yancy (19W).

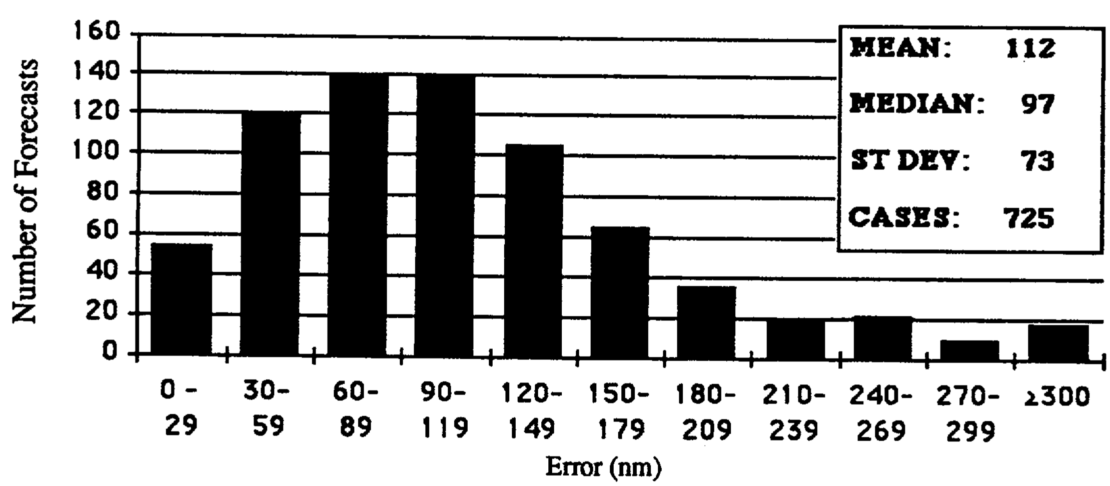


Figure 5-2c Frequency distribution of 24-hour forecast errors (30-nm increments) for the western North Pacific Ocean in 1993. The largest error, 484 nm, occurred on Tropical Storm Irma (02W).

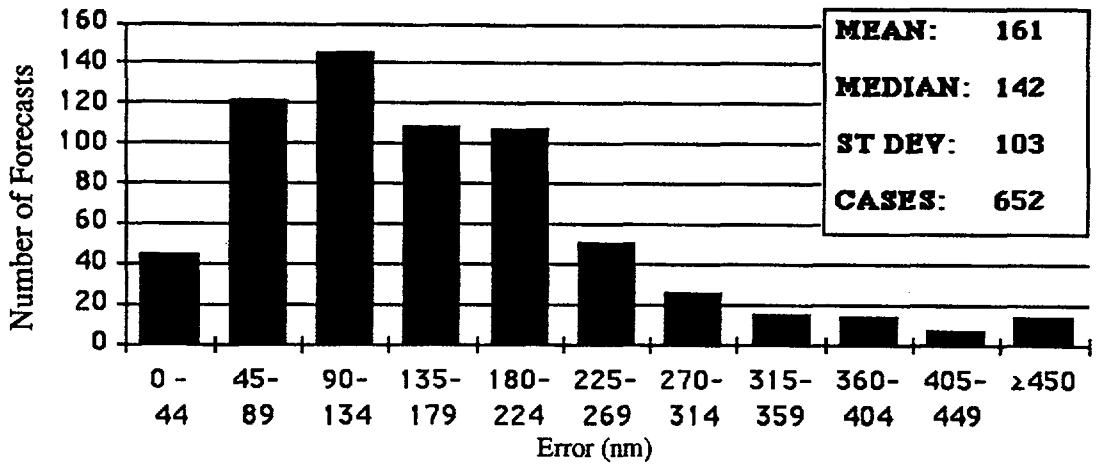


Figure 5-2d Frequency distribution of 36-hour forecast errors (45-nm increments) for the western North Pacific Ocean in 1993. The largest error, 674 nm, occurred on Typhoon Flo (26W).

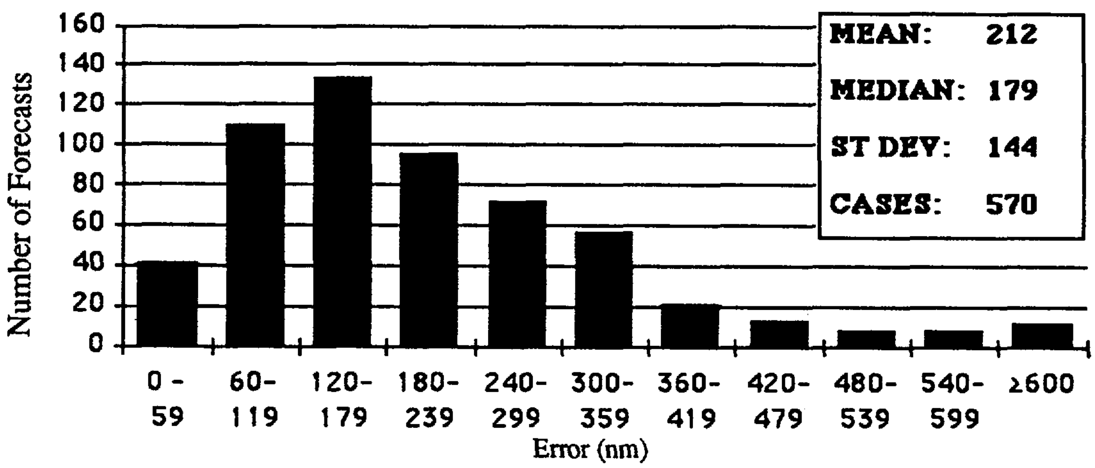


Figure 5-2e Frequency distribution of 48- hour forecast errors (60-nm increments) for the western North Pacific Ocean in 1993. The largest error, 1075 nm, occurred on Typhoon Flo (26W).

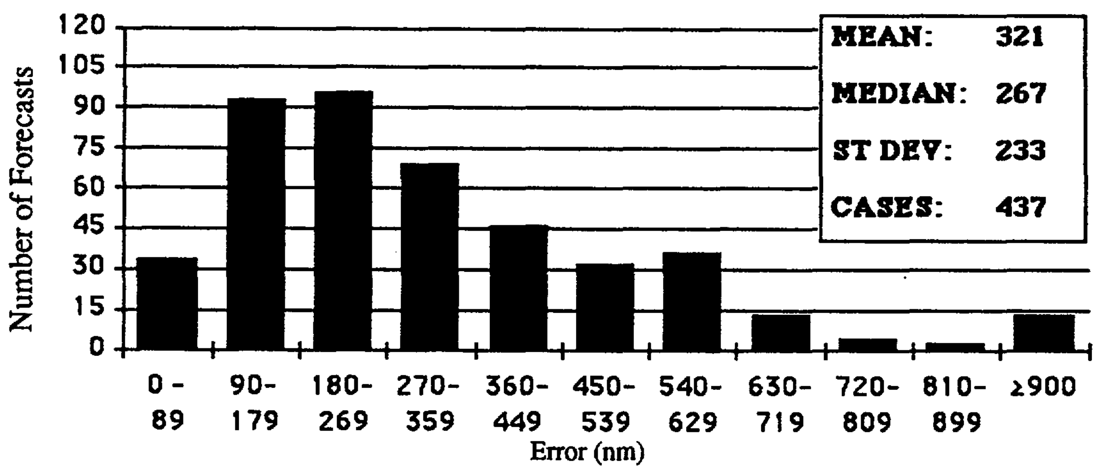


Figure 5-2f Frequency distribution of 72-hour forecast errors (90-nm increments) for the western North Pacific Ocean in 1993. The largest error, 1732 nm, occurred on Typhoon Flo (26W).

Table 5-1 INITIAL WARNING POSITION AND FORECAST ERRORS (NM) FOR THE WESTERN NORTH PACIFIC 1978-1993.

YEAR	NUMBER OF WARNINGS	INITIAL POSITION	NUMBER OF FORECASTS	24-HOUR TRACK	24-HOUR ALONG	24-HOUR CROSS	NUMBER OF FORECASTS	48-HOUR TRACK	48-HOUR ALONG	48-HOUR CROSS	NUMBER OF FORECASTS	72-HOUR TRACK	72-HOUR ALONG	72-HOUR CROSS
1978	696	21	556	126	87	71	420	274	194	151	295	411	296	218
1979	695	25	589	125	81	76	469	227	146	138	366	316	214	182
1980	590	28	491	127	86	76	369	244	165	147	267	391	266	230
1981	584	25	466	124	80	77	348	221	146	131	246	334	206	219
1982	786	19	666	113	74	70	532	238	162	142	425	342	223	211
1983	445	16	342	117	76	73	253	260	169	164	184	407	259	263
1984	611	22	492	117	84	64	378	232	163	131	286	363	238	216
1985	592	18	477	117	80	68	336	231	153	138	241	367	230	227
1986	743	21	645	126	85	70	535	261	183	151	412	394	276	227
1987	657	18	563	107	71	64	465	204	134	127	389	303	198	186
1988	465	23	373	114	85	58	262	216	170	103	183	315	244	159
1989	710	20	625	120	83	69	481	231	162	127	363	350	265	177
1990	794	21	658	103	72	60	525	203	148	110	432	310	225	168
1991	835	22	733	96	69	53	599	185	137	97	484	287	229	146
1992	941	25	841	107	77	59	687	205	143	116	568	305	210	172
1993	853	26	725	112	79	63	570	212	151	117	437	321	226	173
AVERAGE 1978-1993	687	22	578	116	79	67	452	227	157	131	348	345	238	198

Note: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were recomputed as cross-track and along-track errors after-the-fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track errors.

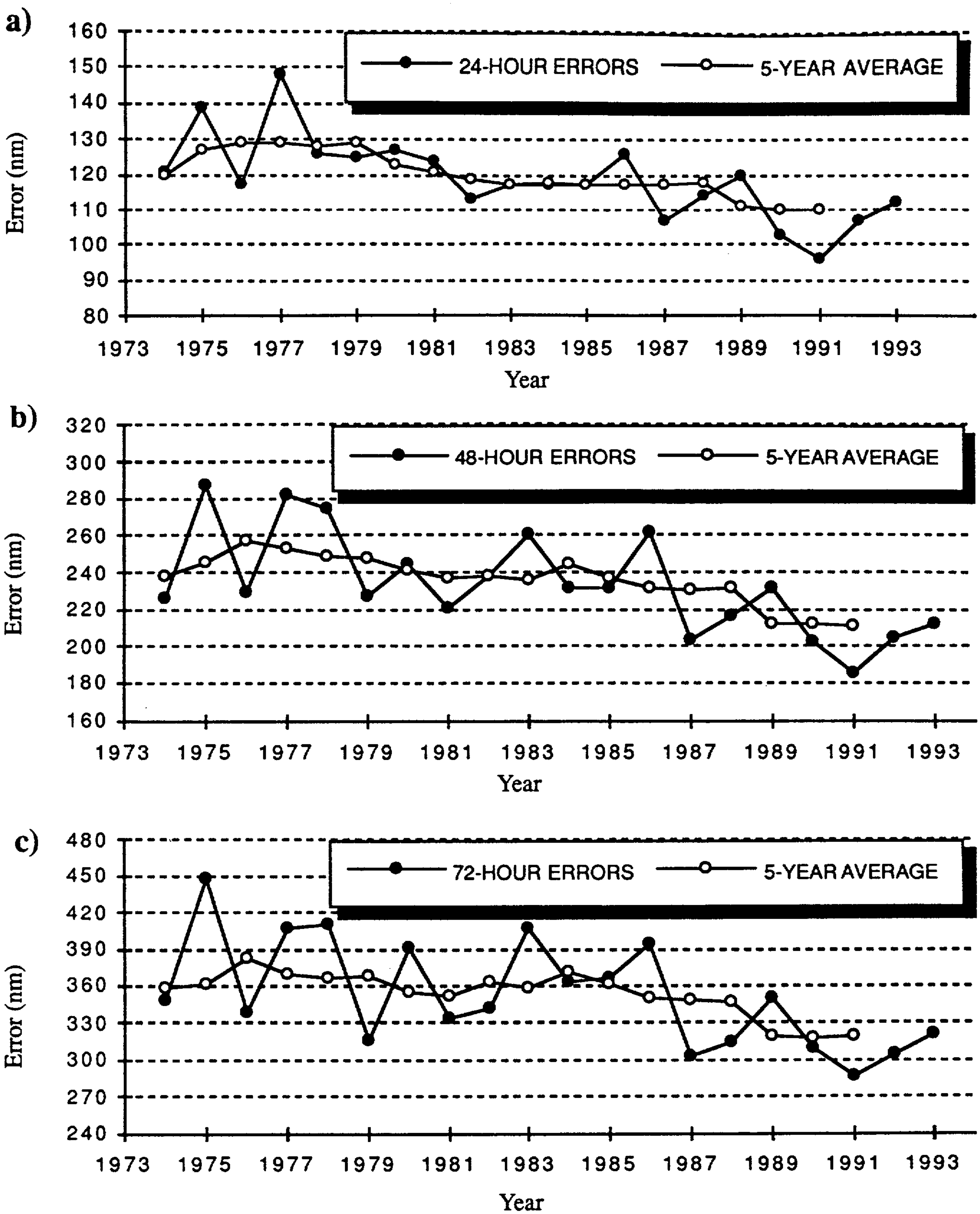


Figure 5-3 Mean track forecast error (nm) and 5-year running mean for a) 24 hours, b) 48 hours and c) 72 hours for the western North Pacific Ocean for the period 1974 to 1993.

Table 5-2 MEAN FORECAST ERRORS (NM) WESTERN NORTH PACIFIC FOR 1959-1993

	24-HOUR		48-HOUR		72-HOUR	
YEAR	ALL /	TYPHOONS*	ALL /	TYPHOONS*	ALL /	TYPHOONS*
1959		117**		267**		
1960		177**		354**		
1961		136		274		
1962		144		287		476
1963		127		246		374
1964		133		284		429
1965		151		303		418
1966		136		280		432
1967		125		276		414
1968		105		229		337
1969		111		237		349
1970	104	98	190	181	279	272
1971	111	99	212	203	317	308
1972	117	116	245	245	381	382
1973	108	102	197	193	253	245
1974	120	114	226	218	348	357
1975	138	129	288	279	450	442
1976	117	117	230	232	338	336
1977	148	140	283	266	407	390
1978	127	120	271	241	410	459
1979	124	113	226	219	316	319
1980	126	116	243	221	389	362
1981	123	117	220	215	334	342
1982	113	114	237	229	341	337
1983	117	110	259	247	405	384
1984	117	110	233	228	363	361
1985	117	112	231	228	367	355
1986	121	117	261	261	394	403
1987	107	101	204	211	303	318
1988	114	107	216	222	315	327
1989	120	107	231	214	350	325
1990	103	98	203	191	310	299
1991	96	93	185	187	286	298
1992	107	97	205	194	305	295
1993	112	102	212	205	321	320

* Forecasts were verified when the tropical cyclone intensities were at least 35 kt (18 m/sec).

** Forecast positions north of 35° north latitude were not verified

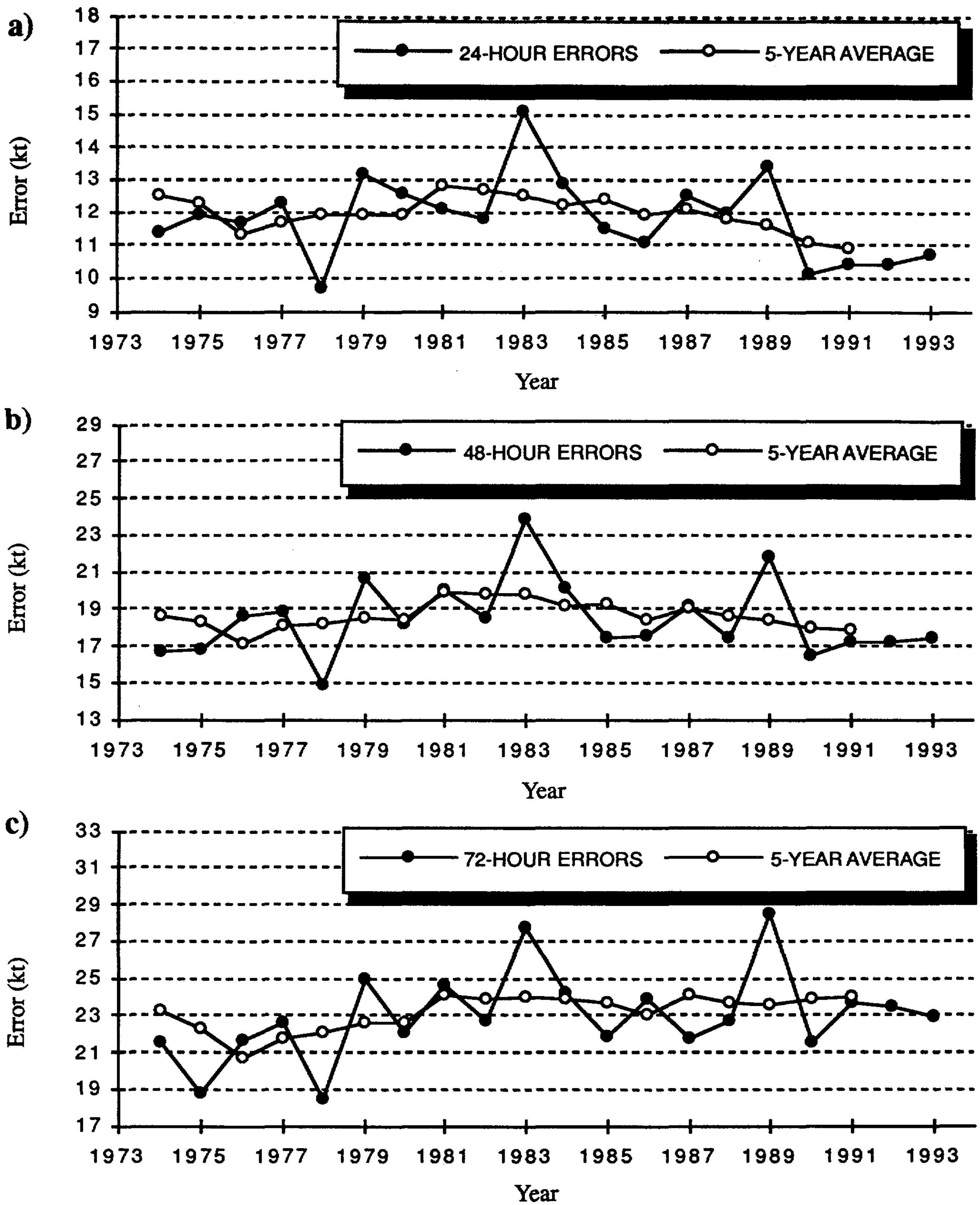


Figure 5-4 Mean intensity forecast errors (kt) and 5-year running mean for a) 24 hours, b) 48 hours and c) 72 hours for the western North Pacific Ocean for the period 1974 to 1993.

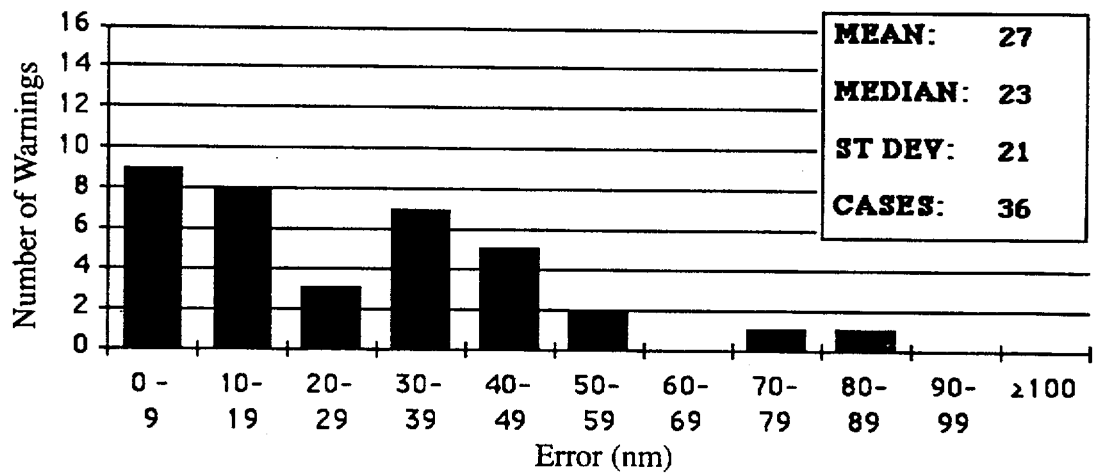


Figure 5-5a Frequency distribution of initial warning position errors (10-nm increments) for the North Indian Ocean in 1993. The largest error, 85 nm, was on TC02B.

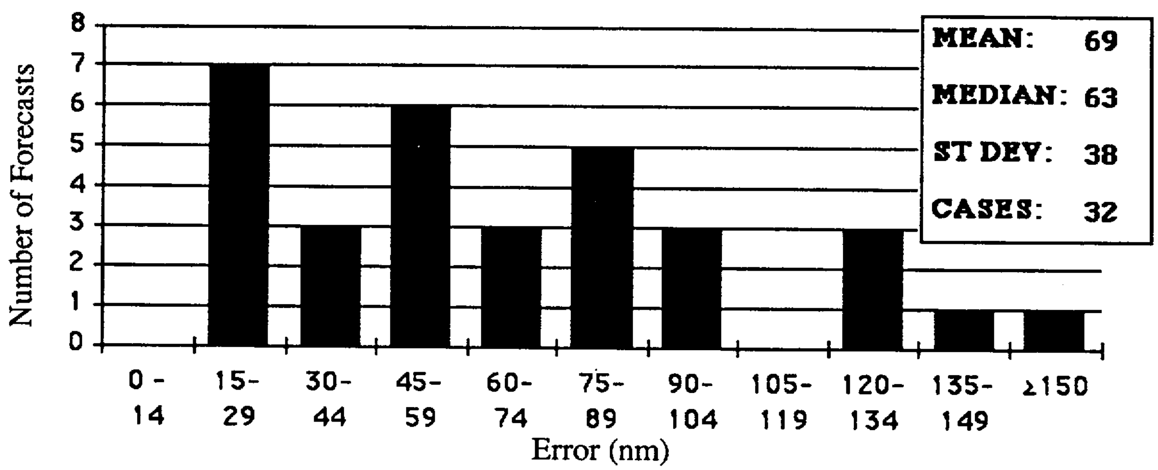


Figure 5-5b Frequency distribution of 12-hour forecast errors (15-nm increments) for the North Indian Ocean in 1993. The largest error, 163 nm, was on TC01A.

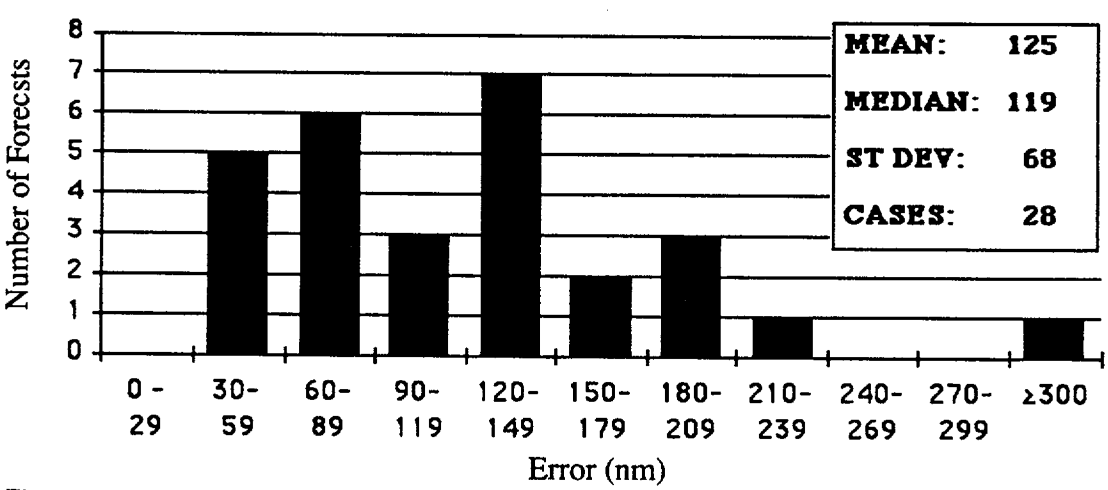


Figure 5-5c Frequency distribution of 24-hour forecast errors (30-nm increments) for the North Indian Ocean in 1993. The largest error, 356 nm, was on TC01A.

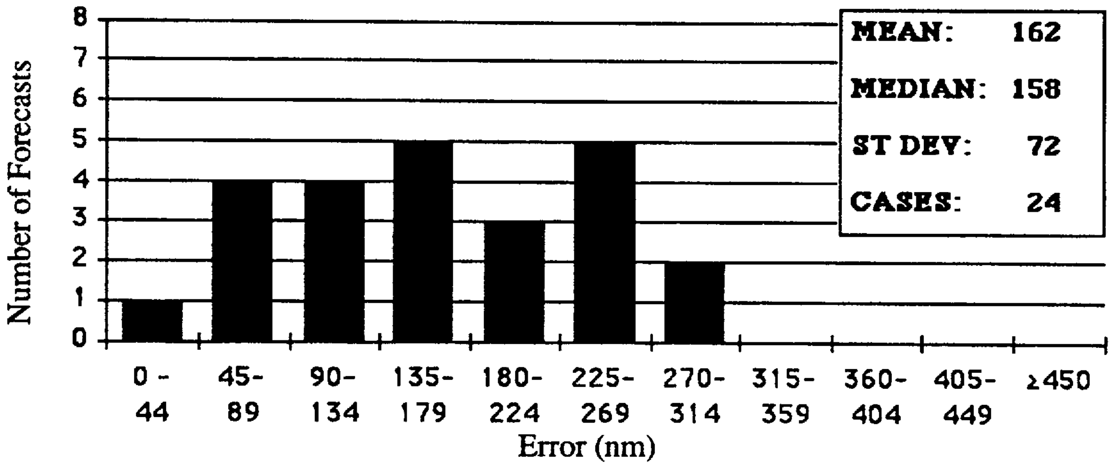


Figure 5-5d Frequency distribution of 36-hour forecast errors (45-nm increments) for the North Indian Ocean in 1993. The largest error, 286 nm, was on TC01A.

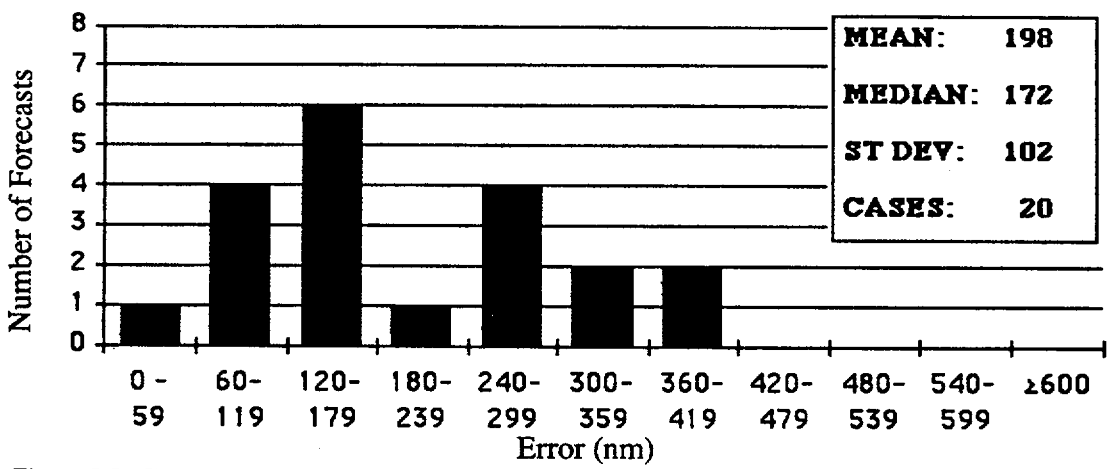


Figure 5-5e Frequency distribution of 48-hour forecast errors (60-nm increments) for the North Indian Ocean in 1993. The largest error, 395 nm, was on TC01A.

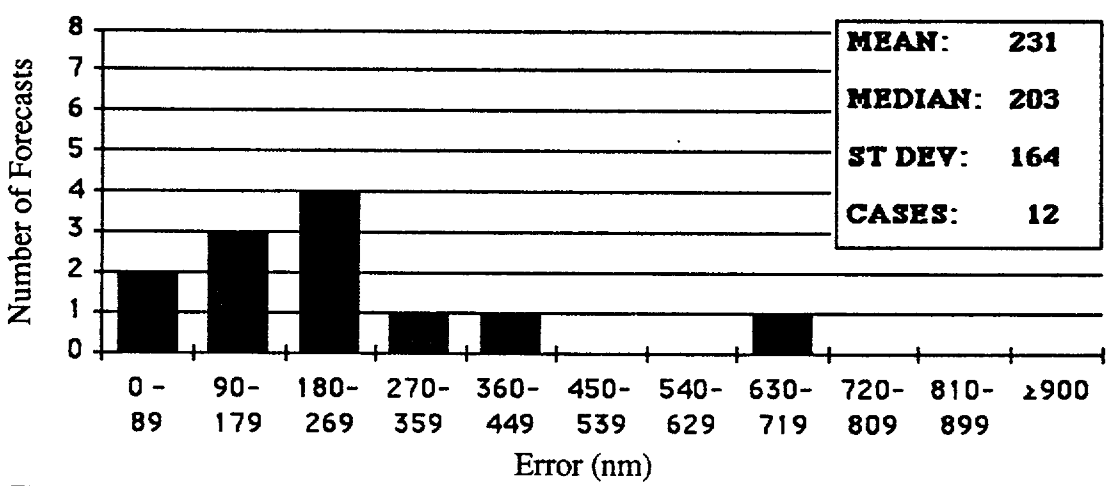


Figure 5-5f Frequency distribution of 72-hour forecast errors (90-nm increments) for the North Indian Ocean in 1993. The largest error, 651 nm, was on TC01A.

Table 5-3 INITIAL POSITION AND FORECAST POSITION ERRORS (NM) FOR THE NORTH INDIAN OCEAN 1978-1993

YEAR	NUMBER OF WARNINGS	**INITIAL POSITION**	NUMBER OF FORECASTS	**24-HOUR** TRACK	ALONG	CROSS	NUMBER OF FORECASTS	**48-HOUR** TRACK	ALONG	CROSS	NUMBER OF FORECASTS	**72-HOUR** TRACK	ALONG	CROSS
1978	32	43	28	133	90	82	19	202	147	109	N/A			
1979	93	46	63	151	96	95	17	278	193	161	17	437	251	320
1980	14	41	7	115	81	71	38	93	25	88	1	167	97	137
1981	41	28	29	109	76	63	2	176	120	109	5	197	150	111
1982	55	35	37	138	110	68	17	368	292	209	7	762	653	332
1983	18	38	7	117	90	50	18	153	137	53	0			
1984	67	33	42	154	124	67	20	274	217	139	16	388	339	121
1985	53	31	30	122	102	53	8	242	119	194	0			
1986	28	52	16	134	118	53	7	168	131	80	5	269	189	180
1987	83	42	54	144	91	100	25	205	125	140	21	305	219	188
1988	44	34	30	120	89	63	18	219	112	176	12	409	227	303
1989	44	19	33	88	62	50	17	146	94	86	12	216	164	111
1990	46	31	36	101	85	43	24	146	117	67	17	185	130	104
1991	56	38	43	129	107	54	27	235	200	89	14	450	356	178
1992	191	35	149	128	73	86	100	244	141	166	62	398	276	218
1993	36	27	28	125	87	79	20	198	171	74	12	231	176	116
AVERAGE 1978-1993	56	36	40	129	90	74	24	212	142	127	13	360	258	196

Note: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were recomputed as cross-track and along-track errors after-the-fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track errors.

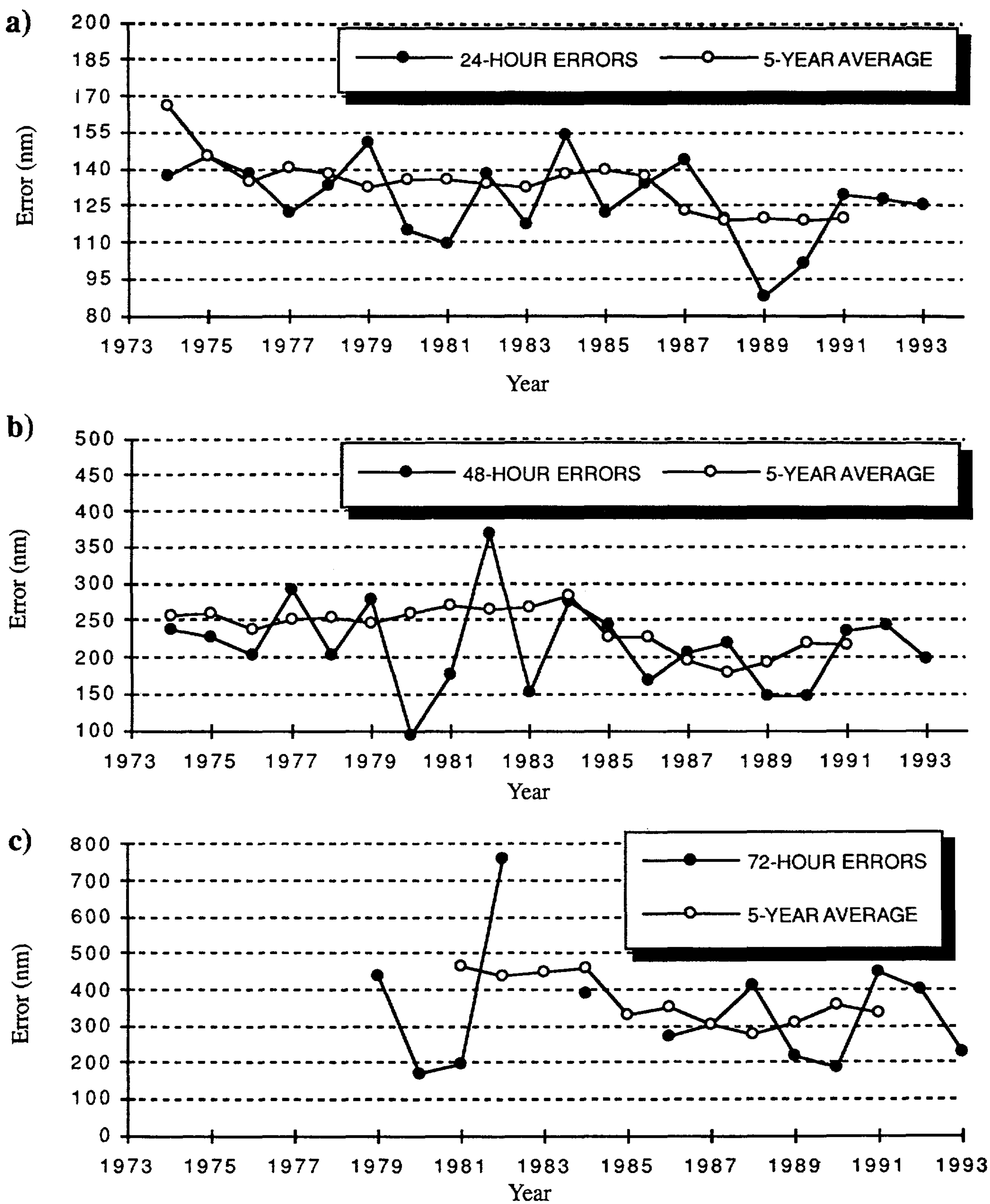


Figure 5-6 Mean track errors (nm) and 5-year running mean for a) 24 hours, b) 48 hours and c) 72 hours in the North Indian Ocean for the period 1974 to 1993. Note: no 72-hour forecasts verified prior to 1979, and in 1983 and 1985.

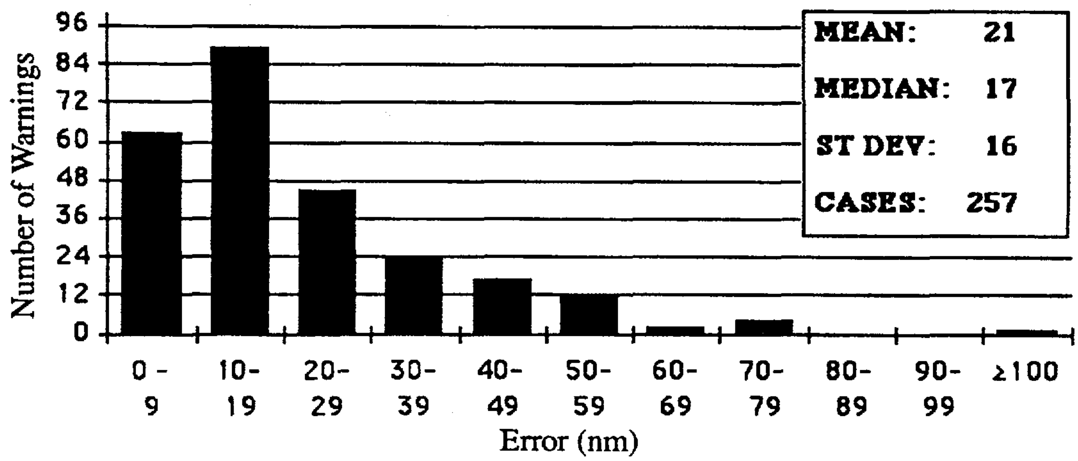


Figure 5-7a Frequency distribution of initial warning position errors (10-nm increments) for the South Pacific and South Indian Oceans in 1993. The largest error, 101 nm, occurred on Tropical Cyclone 02S (Babie).

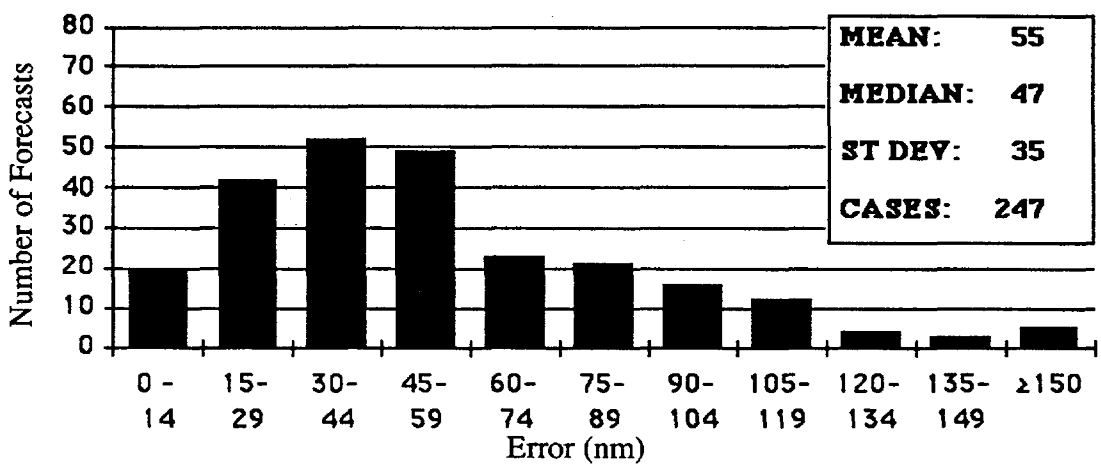


Figure 5-7b Frequency distribution of 12-hour forecast errors (15-nm increments) for the South Pacific and South Indian Oceans in 1993. The largest error, 217 nm, occurred on Tropical Cyclone 27P (Adel).

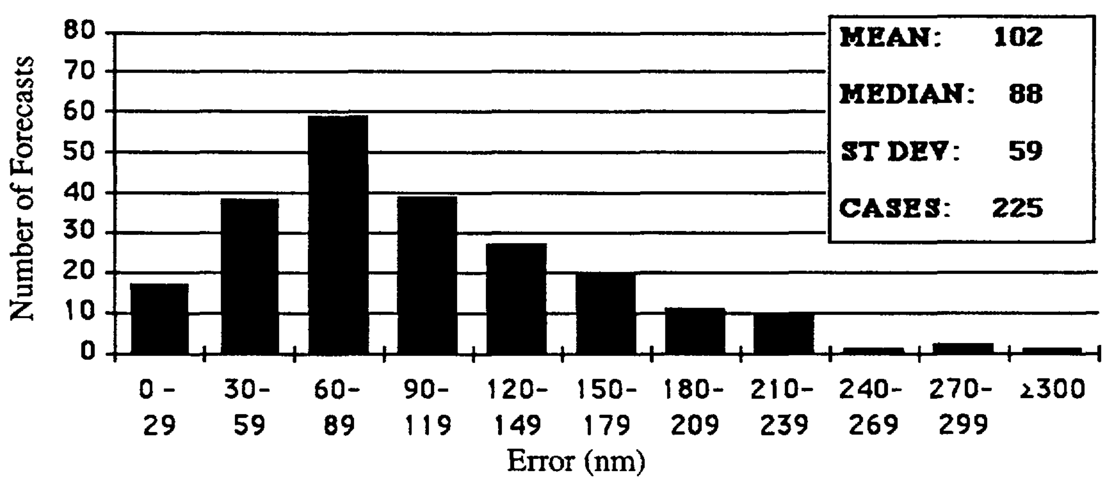


Figure 5-7c Frequency distribution of 24-hour forecast errors (30-nm increments) for the South Pacific and South Indian Oceans in 1993. The largest error, 310 nm, occurred on Tropical Cyclone 21P (Polly).

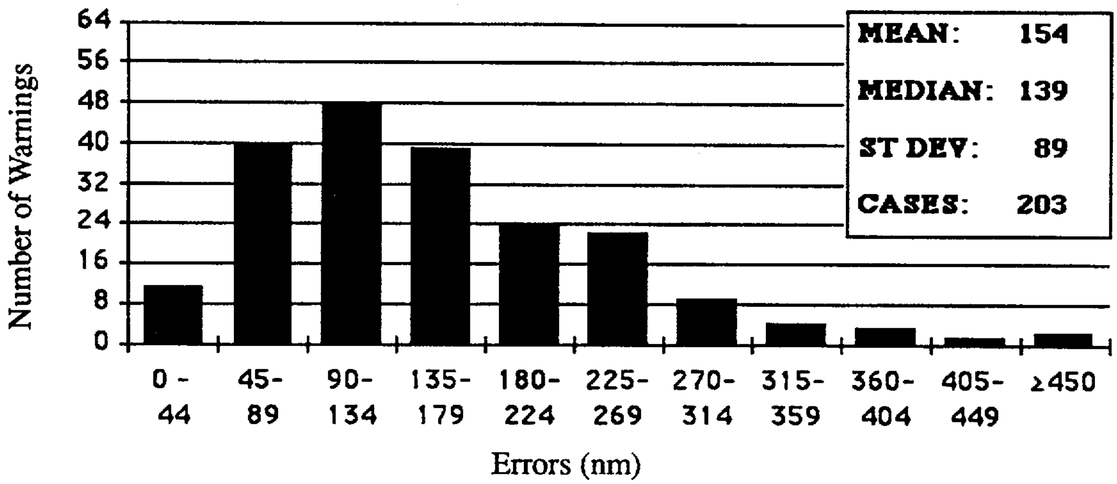


Figure 5-7d Frequency distribution of 36-hr forecast errors (45-nm increments) for the South Pacific and South Indian Oceans in 1993. The largest error, 485 nm, occurred on Tropical Cyclone 21P (Polly).

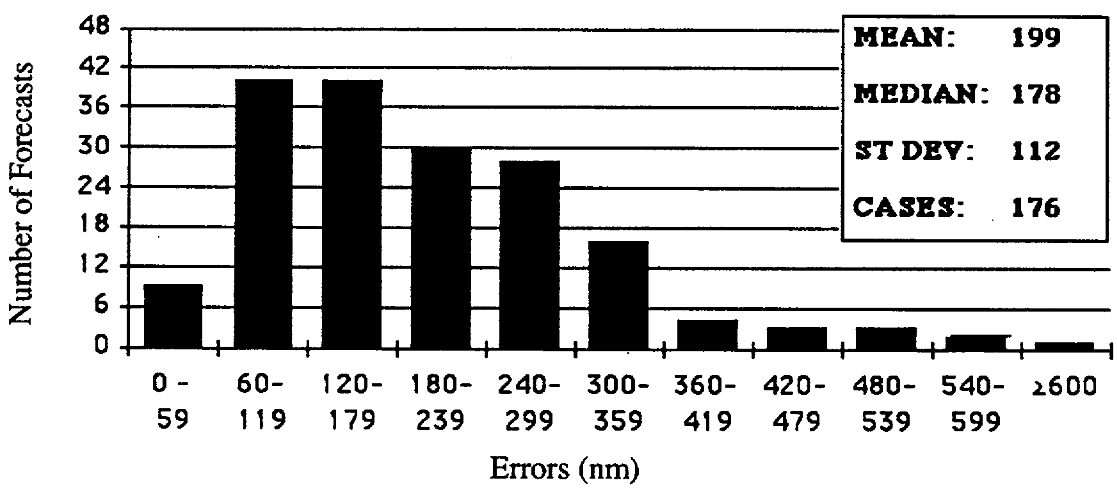


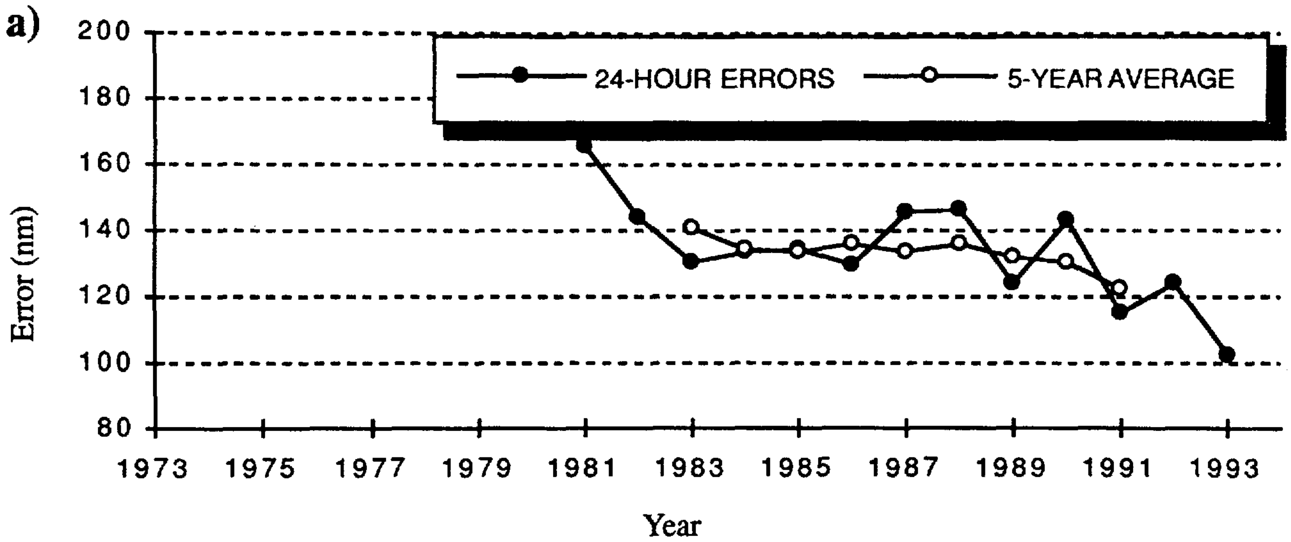
Figure 5-7e Frequency distribution of 48-hour forecast errors (60-nm increments) for the South Pacific and South Indian Oceans in 1993. The largest error, 618 nm, occurred on Tropical Cyclone 23P (Prema).

Table 5-4 INITIAL POSITION AND FORECAST POSITION ERRORS (NM) FOR THE SOUTHERN HEMISPHERE 1981-1993

YEAR	NUMBER OF WARNINGS	**INITIAL POSITION**	NUMBER OF FORECASTS	**24-HOUR** TRACK	ALONG	CROSS	NUMBER OF FORECASTS	**48-HOUR** TRACK	ALONG	CROSS
1981	226	48	190	165	103	106	140	315	204	201
1982	275	38	238	144	98	86	176	274	188	164
1983*	191	35	163	130	88	77	126	241	158	145
1984	301	36	252	133	90	79	191	231	159	134
1985*	306	36	257	134	92	79	193	236	169	132
1986*	279	40	227	129	86	77	171	262	169	164
1987*	189	46	138	145	94	90	101	280	153	138
1988*	204	34	99	146	98	83	48	290	246	144
1989*	287	31	242	124	84	73	186	240	166	136
1990*	272	27	228	143	105	74	177	263	178	152
1991*	264	24	231	115	75	69	185	220	152	129
1992*	267	28	230	124	91	64	208	240	177	129
1993*	257	21	225	102	74	57	176	199	142	114
AVERAGE 1981-1993	255	34	209	132	90	77	160	248	170	144

* These statistics are for JTWC forecasts only. NPMOC statistics are not included.

Note: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were recomputed as cross-track and along-track errors after-the-fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track errors.



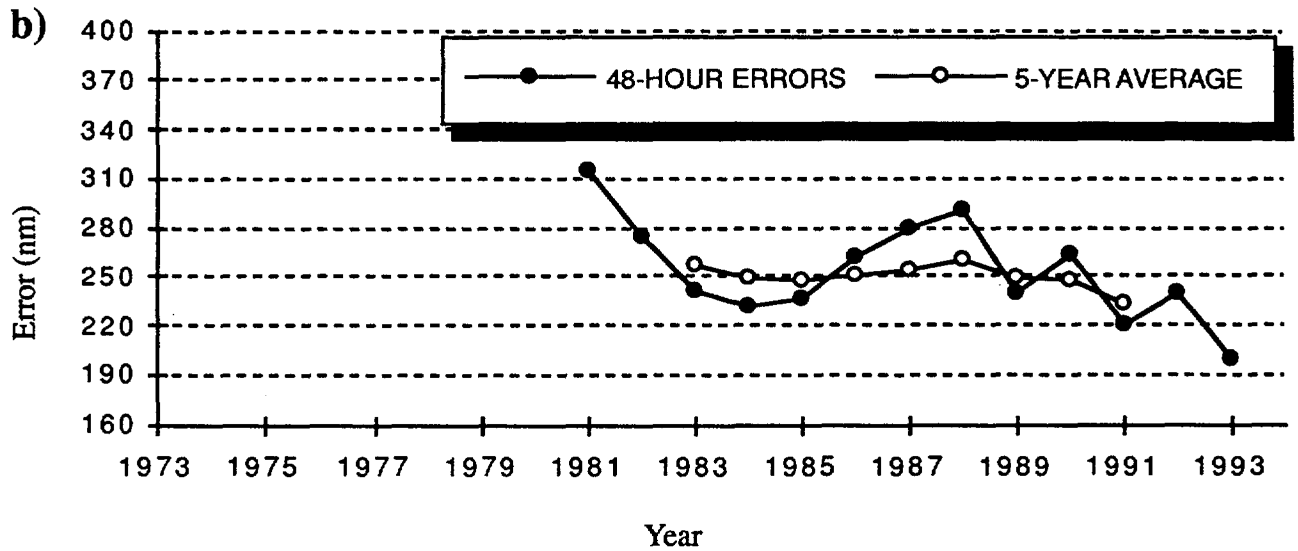


Figure 5-8 Mean track forecast errors (nm) and 5-year running mean for a) 24 hours and b) 48 hours for the South Pacific and South Indian Oceans for the period 1981 to 1993.

5.2 COMPARISON OF OBJECTIVE TECHNIQUES

JTWC uses a variety of objective techniques for guidance in the warning preparation process. Multiple techniques are required, because each technique has particular strengths and weaknesses which vary by basin, numerical model initialization, time of year, synoptic situation and forecast period. The accuracy of objective aid forecasts depends on both the specified position and the past motion of the tropical cyclone as determined by the working best track. JTWC initializes its objective techniques using an extrapolated working best track position so that the output of the techniques will start at the valid time of the next warning initial position.

Unless stated otherwise, all the objective techniques discussed below run in all basins covered by JTWC's AOR and provide forecast positions at 12-, 24-, 36-, 48-, and 72-hours unless the technique aborts prematurely during computations. The techniques can be divided into six general categories: extrapolation, climatology and analogs, statistical, dynamic, hybrids, and empirical or analytical.

5.2.1 EXTRAPOLATION (XTRP) — Past speed and direction are computed using the rhumb line distance between the current and 12-hour old positions of the tropical cyclone. Extrapolation from the current warning position is used to compute forecast positions.

5.2.2 CLIMATOLOGY and ANALOGS

5.2.2.1 CLIMATOLOGY (CLIM) — Employs time and location windows relative to the current position of the storm to determine which historical storms will be used to compute the forecast. The historical data base is 1945-1981 for the Northwest Pacific, and 1900 to 1990 for the rest of JTWC's AOR. A second climatology-based technique exists on JTWC's Macintosh®™ computers. It employs data bases from 1945 to 1992 and from 1970 to 1993. The latter is referred to as the satellite-era data base. Objective intensity forecasts are available from these data bases. Scatter diagrams of expected tropical cyclone motion at bifurcation points are also available from these data bases.

5.2.2.2 ANALOGS — JTWC's analog and climatology techniques use the same historical data base, except that the analog approach imposes more restrictions on which storms will be used to compute the forecast positions. Analogs in all basins must satisfy time, location, speed, and direction windows, although the window definitions are distinctly different in the Northwest Pacific. In this basin, acceptable analogs are also ranked in terms of a similarity index that includes the above parameters and: storm size and size change, intensity and intensity change, and heights and locations of the 700-mb subtropical ridge and upstream midlatitude trough. In other basins, all acceptable analogs receive equal weighting and a persistence bias is explicitly added to the forecast. In the western North Pacific basin, analog weighting is varied using the similarity index, and a persistence bias is implicitly incorporated by rotating the analog tracks so that they initially match the 12-hr old motion of the current storm. In the AOR, a forecast based on all acceptable straight-running analogs called STRT, as well as a forecast based only on historical recurvers called RECR are available.

5.2.3 STATISTICAL

5.2.3.1 CLIMATOLOGY AND PERSISTENCE (CLIPER or CLIP) — A statistical regression technique that is based on climatology, current position and 12-hour and 24-hour past movement. This technique is used as a crude baseline against which to measure the forecast skill of other, more sophisticated techniques. CLIP in

the Northwest Pacific uses third-order regression equations, and is based on the work of Xu and Neumann (1985). CLIPER has been available outside this basin since mid-1990, with regression coefficients recently recomputed by FNOC based on the updated 1900-1989 data base.

5.2.3.2 COLORADO STATE UNIVERSITY MODEL (CSUM) — A statistical-dynamical technique based on the work of Matsumoto (1984). Predictor parameters include the current and 24-hr old position of the storm, heights from the current and 24-hr old NOGAPS 500-mb analyses, and heights from the 24-hr and 48-hr NOGAPS 500 mb prognoses. Height values from 200-mb fields are substituted for storms that have an intensity exceeding 90 kt and are located north of the subtropical ridge. Three distinct sets of regression equations are used depending on whether the storm's direction of motion falls into "below," "on," or "above" the subtropical ridge categories. During the development of the regression equation coefficients for CSUM, the so-called "perfect prog" approach was used, in which verifying analyses were substituted for the numerical prognoses that are used when CSUM is run operationally. Thus, CSUM was not "tuned" to any particular version of NOGAPS, and in fact, the performance of CSUM should presumably improve as new versions of NOGAPS improve. CSUM runs only in the Northwest Pacific, South China Sea, and North Indian Ocean basins.

5.2.3.3 JTWC92 or JT92 - JTWC92 is a statistical-dynamical model for the western North Pacific Ocean basin which forecasts tropical cyclone positions at 12-hour intervals to 72 hours. The model uses the deep-layer mean height field derived from the NOGAPS forecast fields. These deep-layer mean height fields are spectrally truncated to wave numbers 0 through 18 prior to use in JTWC92. Separate forecasts are made for each position. That is, the forecast 24 hour position is not a 12-hour forecast from the forecasted 12-hour position.

JTWC92 uses five internal sub-models which are blended and iterated to produce the final forecasts. The first sub-model is a statistical blend of climatology and persistence, known as CLIPER. The second sub-model is an analysis mode predictor, which only uses the "analysis" field. The third sub-model is the forecast mode predictor, which uses only the forecast fields. The fourth sub-model is a combination of 1 and 2 to produce a "first guess" of the 12-hourly forecast positions. The fifth sub-model uses the output of the "first guess" combined with 1,2, and 3 to produce the forecasts. The iteration is accomplished by using the output of sub-model 5 as though it were the output from sub-model 4. The optimum number of iterations has been determined to be three.

When JTWC92 is used in the operational mode, all the NOGAPS fields are forecast fields. The 00Z and 12Z tropical forecasts are based upon the previous 12-hour old synoptic time NOGAPS forecasts. The 06Z and 18Z tropical forecasts are based on the previous 00Z and 12Z NOGAPS forecasts, respectively. Therefore, operationally, the second sub-model uses forecast fields and not analysis fields.

5.2.4 DYNAMIC

5.2.4.1 NOGAPS VORTEX TRACKING ROUTINE (NGPS) — This objective technique follows the movement of the point of minimum height on the 1000 mb pressure surface analyzed and predicted by NOGAPS. A search in the expected vicinity of the storm is conducted every six hours through 72 hours, even if the tracking routine temporarily fails to discern a minimum height point. Explicit insertion of a tropical cyclone bogus via data provided over TYMNET by JTWC began in mid-1990, and has improved the ability of the NOGAPS technique to track the vortex.

5.2.4.2 ONE-WAY (INTERACTIVE) TROPICAL CYCLONE MODEL (OTCM) — This technique is a coarse resolution (205 km grid), three layer, primitive equation model with a horizontal domain of 6400 x 4700 km. OTCM is initialized using 6-hour or 12-hour prognostic fields from the latest NOGAPS run, and the initial fields are smoothed and adjusted in the vicinity of the storm to induce a persistence bias into OTCM's forecast. A symmetric bogus vortex is then inserted, and the boundaries updated every 12 hours by NOGAPS fields as the integration proceeds. The bogus vortex is maintained against frictional dissipation by an analytical heating function. The forecast positions are based on the movement of the vortex in the lowest layer of the model (effectively 850-mb).

5.2.4.3 FNOC BETA AND ADVECTION MODEL (FBAM) — This model is an adaptation of the Beta and Advection model used by NMC. The forecast motion results from a calculation of environmental steering and an empirical correction for the observed vector difference between that steering and the 12-hour old storm motion. The steering is computed from the NOGAPS Deep Layer Mean (DLM) wind fields which are a weighted average of the wind fields computed for the 1000-mb to 100-mb levels. The difference between past storm motion and the DLM steering is treated as if the storm were a Rossby wave with an "effective radius" propagating in response to the horizontal gradient of the coriolis parameter, Beta. The forecast proceeds in one-hour steps, recomputing the effective radius as Beta changes with storm latitude, and blending in a persistence bias for the first 12 hours.

5.2.5 HYBRIDS

Note: For information on hybrid aids under development, refer to Chapter 7, section 7.7 Hybrid Forecast Aids.

5.2.5.1 HALF PERSISTENCE AND CLIMATOLOGY (HPAC) — Forecast positions are generated by equally weighting the forecasts given by XTRP and CLIM.

5.2.5.2 COMBINED CONFIDENCE WEIGHTED FORECASTS (CCWF) — An optimal blend of objective techniques produced by the ATCF. The ATCF blends the selected techniques (currently OTCM, CSUM and HPAC) by using the inverse of the covariance matrices computed from historical and real-time cross-track and along-track errors as the weighting function.

5.2.6 EMPIRICAL OR ANALYTICAL

5.2.6.1 DVORAK — An estimation of a tropical cyclone's current and 24-hour forecast intensity is made from the interpretation of satellite imagery (Dvorak, 1984). These intensity estimates are used with other intensity related data and trends to forecast short-term tropical cyclone intensity.

5.2.6.2 MARTIN/HOLLAND — The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 35-, 50- and 100-kt (18-,26- and 51-m/sec) wind radii around tropical cyclones. It solves equations for basic gradient wind relations within the tropical cyclone area, using input parameters obtained from enhanced infrared satellite imagery. The diagnosis also includes an asymmetric area of winds caused by tropical cyclone movement. Satellite-derived size and intensity parameters are also used to diagnose internal steering components of tropical cyclone motion known collectively as "beta-drift".

5.2.6.3 TYPHOON ACCELERATION PREDICTION TECHNIQUE (TAPT) — This technique (Weir, 1982) utilizes upper-tropospheric and surface wind fields to estimate acceleration associated with the tropical cyclone's interac-

tion with the mid-latitude westerlies. It includes guidelines for the duration of acceleration, upper limits and probable path of the cyclone.

5.3 TESTING AND RESULTS

A comparison of selected techniques is included in Table 5-5 for all Northwest Pacific tropical cyclones, Table 5-6 for all North Indian Ocean tropical cyclones and Table 5-7 for the Southern Hemisphere. For example in Table 5-5 for the 12-hour mean forecast error, 762 cases available for a (homogeneous) comparison, the average forecast error at 12 hours was 74 nm (137 km) for JT92 and 78 nm (145 km) for CLIP. The difference of 4 nm (7 km) is shown in the lower right. (Differences are not always exact, due to computational round-off which occurs for each of the cases available for comparison).

TABLE 5-5 1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWEST PACIFIC (1 JAN 1993 - 31 DEC 1993)

Number of Cases	X-Axis Technique Error
Y-Axis Technique Error	Error Difference (Y-X)

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		CSUM		FBAM		JT92		CLIP		HPAC	
JTWC	800	66														
	66	0														
NGPS	394	56	397	106												
	106	50	106	0												
OTCM	739	65	378	106	755	82										
	82	17	75	-31	82	0										
CSUM	751	65	383	106	753	82	767	78								
	77	12	70	-36	77	-5	78	0								
FBAM	743	65	380	106	744	81	756	77	758	76						
	76	11	70	-36	76	-5	76	-1	76	0						
JT92	749	65	382	106	751	82	763	78	756	76	765	74				
	74	9	67	-39	74	-8	74	-4	74	-2	74	0				
CLIP	751	65	382	106	752	82	764	78	755	76	762	74	767	78		
	78	13	69	-37	78	-4	78	0	78	2	78	4	78	0		
HPAC	749	65	382	106	751	82	764	78	754	76	761	74	765	78	765	80
	80	15	71	-35	79	-3	80	2	80	4	80	6	80	2	80	0

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		CSUM		FBAM		JT92		CLIP		HPAC	
JTWC	725	112														
	112	0														
NGPS	329	98	332	159												
	158	60	159	0												
OTCM	667	110	316	156	684	132										
	132	22	126	-30	132	0										
CSUM	689	111	322	158	682	132	707	129								
	129	18	125	-33	128	-4	129	0								
FBAM	684	111	318	158	676	132	699	129	701	121						
	121	10	118	-40	121	-11	121	-8	121	0						
JT92	689	111	321	157	682	132	705	129	700	121	707	119				
	119	8	115	-42	119	-13	119	-10	119	-2	119	0				
CLIP	687	111	320	158	680	132	703	129	698	122	703	119	705	129		
	129	18	120	-38	127	-5	129	0	129	7	129	10	129	0		
HPAC	686	111	320	158	679	132	703	129	697	121	702	119	704	129	704	135
	135	24	129	-29	133	1	135	6	135	14	135	16	135	6	135	0

Table 5-5 (CONTINUED) 1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWESTERN PACIFIC (1 JAN 1993 - 31 DEC 1993)

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	CSUM	FBAM	JT92	CLIP	HPAC
JTWC	652 161							
	161 0							
NGPS	262 141	265 206						
	206 65	206 0						
OTCM	582 156	249 203	599 186					
	186 30	173 -30	186 0					
CSUM	619 160	257 205	597 186	638 183				
	183 23	180 -25	177 -9	183 0				
FBAM	616 160	254 205	593 185	632 183	634 173			
	173 13	174 -31	169 -16	173 -10	173 0			
JT92	619 160	256 205	597 186	636 183	633 173	638 167		
	167 7	165 -40	164 -22	167 -16	168 -5	167 0		
CLIP	618 160	256 205	597 186	635 183	631 173	635 168	637 187	
	187 27	176 -29	182 -4	187 4	188 15	187 19	187 0	
HPAC	617 160	256 205	596 186	635 183	630 173	634 167	636 187	636 195
	195 35	190 -15	188 2	195 12	195 22	195 28	195 8	195 0

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	CSUM	FBAM	JT92	CLIP	HPAC
JTWC	570 212							
	212 0							
NGPS	200 185	206 250						
	250 65	250 0						
OTCM	499 204	194 246	531 237					
	235 31	218 -28	237 0					
CSUM	544 210	202 249	529 237	580 236				
	233 23	227 -22	227 -10	236 0				
FBAM	540 210	199 250	524 237	573 236	575 230			
	228 18	237 -13	224 -13	229 -7	230 0			
JT92	544 210	202 249	529 238	578 236	574 230	580 224		
	223 13	218 -31	219 -19	224 -12	224 -6	224 0		
CLIP	543 211	200 249	528 238	577 236	573 230	577 224	579 246	
	245 34	227 -22	239 1	247 11	246 16	247 23	246 0	
HPAC	542 210	200 249	527 238	577 236	572 230	576 224	578 246	578 255
	254 44	246 -3	245 7	255 19	254 24	255 31	255 9	255 0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	CSUM	FBAM	JT92	CLIP	HPAC
JTWC	437 321							
	321 0							
NGPS	129 271	136 306						
	305 34	306 0						
OTCM	365 297	120 302	399 341					
	341 44	317 15	341 0					
CSUM	414 319	134 305	398 341	456 342				
	342 23	341 36	322 -19	342 0				
FBAM	412 320	131 308	395 342	452 343	453 348			
	343 23	339 31	332 -10	348 5	348 0			
JT92	325 328	108 311	309 340	356 346	355 346	357 336		
	336 8	341 30	317 -23	336 -10	337 -9	336 0		
CLIP	413 320	133 305	397 342	454 343	452 349	355 337	455 364	
	368 48	357 52	343 1	364 21	364 15	365 28	364 0	
HPAC	412 320	133 305	396 341	454 343	451 349	354 337	454 364	454 365
	363 43	360 55	339 -2	365 22	365 16	366 29	365 1	365 0

TABLE 5-6 1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN (1 JAN 1993 - 31 DEC 1993)

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	32 69						
	69 0						
OTCM	29 67	29 84					
	84 17	84 0					
FBAM	29 65	28 84	29 83				
	83 18	83 -1	83 0				
CLIP	31 69	29 84	29 83	31 79			
	79 10	80 -4	78 -5	79 0			
HPAC	30 66	29 84	29 83	30 78	30 73		
	73 7	75 -9	73 -10	73 -5	73 0		
STRT	26 62	25 76	26 72	26 72	26 67	26 77	
	77 15	79 3	77 5	77 5	77 10	77 0	
CLIM	30 66	29 84	29 83	30 78	30 73	26 77	30 77
	77 11	79 -5	77 -6	77 -1	77 4	74 -3	77 0

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	28 125						
	125 0						
OTCM	25 118	25 149					
	149 31	149 0					
FBAM	25 117	24 148	25 143				
	143 26	143 -5	143 0				
CLIP	27 127	25 149	25 143	27 126			
	126 -1	122 -27	121 -22	126 0			
HPAC	26 118	25 149	25 143	26 120	26 115		
	115 -3	117 -32	114 -29	115 -5	115 0		
STRT	24 115	23 144	24 135	24 119	24 112	24 128	
	128 13	131 -13	128 -7	128 9	128 16	128 0	
CLIM	26 118	25 149	25 143	26 120	26 115	24 128	26 128
	128 10	130 -19	130 -13	128 8	128 13	129 1	128 0

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	24 162						
	162 0						
OTCM	17 149	17 201					
	201 52	201 0					
FBAM	22 166	17 201	22 205				
	205 39	213 12	205 0				
CLIP	23 166	17 201	22 205	23 165			
	165 -1	156 -45	166 -39	165 0			
HPAC	23 166	17 201	22 205	23 165	23 167		
	167 1	147 -54	166 -39	167 2	167 0		
STRT	21 162	16 200	21 196	21 168	21 167	21 175	
	175 13	141 -59	175 -21	175 7	175 8	175 0	
CLIM	23 166	17 201	22 205	23 165	23 167	21 175	23 178
	178 12	168 -33	182 -23	178 13	178 11	189 14	178 0

TABLE 5-6 (CONTINUED 1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN (1 JAN 1993 - 31 DEC 1993)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	20 198						
	198 0						
OTCM	14 177	14 264					
	264 87	264 0					
FBAM	19 206	14 264	19 276				
	276 70	282 18	276 0				
CLIP	19 206	14 264	19 276	19 205			
	205 -1	187 -77	205 -71	205 0			
HPAC	19 206	14 264	19 276	19 205	19 217		
	217 11	184 -80	217 -59	217 12	217 0		
STRT	19 206	14 264	19 276	19 205	19 217	19 232	
	232 26	171 -93	232 -44	232 27	232 15	232 0	
CLIM	19 206	14 264	19 276	19 205	19 217	19 232	19 242
	242 36	228 -36	242 -34	242 37	242 25	242 10	242 0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	12 231						
	231 0						
OTCM	10 224	10 367					
	367 143	367 0					
FBAM	11 240	10 367	11 406				
	406 166	368 1	406 0				
CLIP	11 240	10 367	11 406	11 235			
	235 -5	236 -131	235 -171	235 0			
HPAC	11 240	10 367	11 406	11 235	11 242		
	242 2	229 -138	242 -164	242 7	242 0		
STRT	11 240	10 367	11 406	11 235	11 242	11 213	
	213 -27	185 -182	213 -193	213 -22	213 -29	213 0	
CLIM	11 240	10 367	11 406	11 235	11 242	11 213	11 376
	376 136	382 15	376 -30	376 141	376 134	376 163	376 0

TABLE 5-7 1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMISPHERE (1 JUL 1992 - 30 JUN 1993)

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		FBAM		CLIP		HPAC		STRT		CLIM	
JTWC	246	55														
	55	0														
NGPS	123	52	213	99												
	103	51	99	0												
OTCM	224	54	167	100	328	69										
	71	17	62	-38	69	0										
FBAM	227	54	166	101	325	69	332	80								
	83	29	78	-23	79	10	80	0								
CLIP	229	54	167	100	328	69	332	80	335	86						
	88	34	77	-23	84	15	86	6	86	0						
HPAC	213	55	157	102	311	69	310	78	313	83	313	69				
	71	16	64	-38	68	-1	69	-9	69	-14	69	0				
STRT	179	52	142	95	260	66	264	79	266	83	244	67	266	67		
	69	17	64	-31	66	0	67	-12	67	-16	67	0	67	0		
CLIM	213	55	157	102	311	69	310	78	313	83	313	69	244	67	313	79
	80	25	73	-29	78	9	79	1	79	-4	79	10	76	9	79	0

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		FBAM		CLIP		HPAC		STRT		CLIM	
JTWC	225	102														
	102	0														
NGPS	119	101	208	149												
	151	50	149	0												
OTCM	203	100	161	149	303	116										
	120	20	106	-43	116	0										
FBAM	212	102	164	151	300	116	315	139								
	140	38	135	-16	137	21	139	0								
CLIP	214	102	165	150	303	116	315	139	318	161						
	164	62	143	-7	155	39	161	22	161	0						
HPAC	198	100	155	151	286	116	293	132	296	151	296	120				
	122	22	113	-38	118	2	119	-13	120	-31	120	0				
STRT	168	98	140	139	245	111	255	135	257	157	235	115	257	120		
	121	23	115	-24	118	7	119	-16	120	-37	117	2	120	0		
CLIM	198	100	155	151	286	116	293	132	296	151	296	120	235	117	296	145
	142	42	135	-16	143	27	145	13	145	-6	145	25	140	23	145	0

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		FBAM		CLIP		HPAC		STRT		CLIM	
JTWC	203	154														
	154	0														
NGPS	105	157	186	182												
	188	31	182	0												
OTCM	180	149	138	174	273	171										
	178	29	156	-18	171	0										
FBAM	190	153	140	178	270	171	288	201								
	203	50	191	13	201	30	201	0								
CLIP	192	153	141	177	273	171	288	201	291	217						
	219	66	198	21	207	36	217	16	217	0						
HPAC	179	148	133	176	259	172	269	191	272	201	272	170				
	170	22	158	-18	166	-6	169	-22	170	-31	170	0				
STRT	152	148	122	163	221	163	236	196	238	210	219	163	238	188		
	175	27	168	5	182	19	187	-9	188	-22	181	18	188	0		
CLIM	179	148	133	176	259	172	269	191	272	201	272	170	219	181	272	207
	200	52	187	11	207	35	207	16	207	6	207	37	202	21	207	0

TABLE 5-7 (CONTINUED)

1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES
IN THE SOUTHERN HEMISPHERE (1 JUL 1992 - 30 JUN 1993)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	176 199							
	199 0							
NGPS	92 208	172 230						
	242 34	230 0						
OTCM	160 197	128 225	248 221					
	229 32	210 -15	221 0					
FBAM	168 199	131 229	245 219	262 265				
	271 72	248 19	263 44	265 0				
CLIP	170 199	132 229	248 221	262 265	265 273			
	269 70	257 28	264 43	273 8	273 0			
HPAC	160 195	124 223	235 222	246 250	249 253	249 218		
	216 21	211 -12	215 -7	217 -33	218 -35	218 0		
STRT	135 192	114 210	202 211	215 262	217 263	201 208	217 237	
	228 36	227 17	231 20	236 -26	237 -26	223 15	237 0	
CLIM	160 195	124 223	235 222	246 250	249 253	249 218	201 223	249 262
	252 57	245 22	265 43	262 12	262 9	262 44	257 34	262 0

6. TROPICAL CYCLONE WARNING VERIFICATION STATISTICS

6.1 GENERAL

Due to the rapid growth of microcomputers in the meteorological community and to save publishing costs, tropical cyclone track data (with best track, initial warning, 12-, 24-, 36-, 48-, and 72-hour JTWC forecasts) and fix data (satellite, aircraft, radar and synoptic) are now available as computer files separately upon request. Best track positions that precede the first warning or that succeed the final warning are not printed in this chapter, but are available on floppy diskettes upon request. The data will be in ASCII format on 5.25 inch "floppy" or 3.5 inch diskettes, and will fill two diskettes (or one high density diskette). These data include the western North Pacific Ocean (1 January - 31 December 1993) on one and North Indian Ocean (1 January - 31 December 1993), and western South Pacific and South Indian Oceans (1 July 1992 - 30 June 1993) on the other. Agencies or individuals desiring these data sets should send the appropriate number of diskettes to NAVPACMETOCCEN WEST/JTWC Guam with their request. When the request and your diskettes are received, the data will be copied onto your diskettes and returned with an explanation of the data formats.

6.2 WARNING VERIFICATION STATISTICS

6.2.1 WESTERN NORTH PACIFIC

This section includes verification statistics for each JTWC tropical cyclone warning in the western North Pacific Ocean during 1993.

JTWC FORECAST TRACK AND INTENSITY ERRORS BY WARNING

TROPICAL DEPRESSION 01W

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93030100	1	8.4N	127.7E	25	11	97	69				0	5	5			
93030106	2	8.3N	125.8E	25	11	5					5	10				
93030112	3	8.0N	124.2E	20	34	110					0	5				
93030118	4	7.6N	123.5E	20	5						0					
93030200	5	7.0N	122.8E	20	42						0					
			AVERAGE		21	71	69				1	7	5			
			# CASES		5	3	1				5	3	1			

TROPICAL STORM IRMA (02W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93031000	1	5.3N	163.9E	30	59	118	169	232	356	304	0	0	5	5	10	-5
93031006	2	5.3N	163.7E	30	34	43	60	146	176	13	0	5	5	5	10	-10
93031012	3	5.3N	163.5E	30	18	21	54	128	80	185	0	5	5	5	5	-15
93031018	4	5.2N	163.2E	25	8	25	96	129	134	192	0	0	5	5	0	-20
93031100	5	5.2N	163.0E	25	18	48	99	59	26	332	0	0	0	-5	-10	-25
93031106*	6	5.1N	162.8E	25	16	81	93	72			0	0	0	-10		
93031118*	7	4.1N	162.5E	25	24	43	8	123			5	0	-5	-15		
93031206*	8	4.4N	162.3E	25	18	47	163	324			5	-5	-15	-25		
93031218	9	5.2N	161.1E	35	46	190	377	481	526	535	0	-10	-15	-10	-10	0
93031300	10	5.9N	160.2E	40	13	139	229	250	262	264	-5	-15	-15	-15	-5	0
93031306	11	7.4N	158.6E	45	29	134	179	179	181	285	-10	-15	-15	-10	-5	0
93031312	12	9.0N	157.0E	50	5	58	92	118	147	320	-5	0	10	20	20	25

* TD Warning Issued

TROPICAL STORM IRMA (02W) (CONTINUED)

DTG	WRN NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93031318	13	10.3N	155.6E	55	56	82	83	96	161	383	-5	5	10	20	10	20
93031400	14	11.3N	154.4E	55	32	46	67	36	188	523	-10	-10	-5	-15	-20	0
93031406	15	11.9N	153.2E	55	8	53	50	152	305	600	-10	-10	-10	-15	-20	5
93031412	16	12.2N	152.2E	55	8	42	107	243	392		-10	-5	-15	-20	-10	
93031418	17	12.5N	151.2E	55	8	33	148	303	455		-10	-10	-15	-10	5	
93031500	18	12.9N	150.3E	50	17	116	266	433	563		0	-5	-5	5	15	
93031506	19	13.5N	149.7E	50	29	117	225	314	389		0	-5	-5	5	20	
93031512	20	14.3N	149.5E	55	30	94	195	210			0	0	5	10		
93031518	21	15.1N	149.6E	55	35	133	213	342			0	0	10	15		
93031600	22	15.8N	149.8E	55	42	173	392				5	5	10			
93031606	23	16.5N	150.2E	55	70	247	484				0	5	10			
93031612	24	17.0N	150.6E	50	54	186					0	5				
93031618	25	17.3N	151.0E	45	87	204					0	10				
93031700	26	17.5N	151.4E	40	6						0					
93031706	27	17.7N	151.8E	35	8						0					
			AVERAGE		29	99	168	209	272	328	3	5	8	12	11	10
			# CASES		27	25	23	21	16	12	27	25	23	21	16	12

TROPICAL DEPRESSION 03W

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93041218	1	6.7N	128.0E	25	30	13	8	21			0	0	5	10		
93041300	2	6.6N	127.2E	25	26	8	21				0	5	5			
93041306	3	6.4N	126.5E	25	13	12	21				0	5	5			
93041312*	4	6.4N	125.8E	20	12	18					0	0				
93041400	5	6.4N	124.3E	20	11						0					
			AVERAGE		19	13	17	22			0	3	5	10		
			# CASES		5	4	3	1			5	4	3	1		

* TD Warning Issued

TROPICAL DEPRESSION 04W

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93042006	1	9.8N	152.3E	25	25	93	189	280	358	523	0	5	10	15	20	20
93042012	2	9.6N	151.3E	25	8	84	163	224	290	390	0	5	10	15	15	20
93042018	3	9.1N	150.4E	25	41	118	199	249	305	370	0	5	10	15	15	20
93042100	4	8.5N	149.7E	25	11	41	72	108	140	160	5	5	10	5	10	15
93042106	5	8.0N	149.0E	25	6	48	78	102	123	124	5	5	10	5	10	15
93042112	6	7.5N	148.4E	25	8	37	70	107	132	160	0	5	0	0	5	5
93042118	7	7.2N	147.7E	25	24	66	108	150	180	191	0	5	0	0	5	5
93042200	8	6.9N	146.9E	25	24	60	80	91	85	67	0	0	0	0	5	5
93042206	9	6.6N	146.0E	25	77	119	169	202	198	175	0	-5	0	0	0	5
93042212	10	6.3N	145.2E	30	101	147	177	184	178	200	-5	-5	-5	0	0	5
93042218	11	6.1N	144.3E	30	118	169	207	203	196	195	-5	-5	0	0	5	15
93042300	12	5.9N	143.3E	30	29	30	21	32	45	92	-5	-5	0	0	5	15
93042306	13	5.8N	142.3E	30	13	18	18	48	35	72	0	5	10	10	15	25
93042312	14	5.7N	141.3E	30	49	102	152	167	173	205	0	0	5	10	15	25
93042318	15	5.7N	140.3E	30	18	53	82	91	130	223	0	0	5	10	20	25
93042400	16	5.9N	139.4E	30	26	64	77	83	122	248	0	0	5	10	20	25
93042406	17	6.2N	138.6E	30	30	48	59	24	30	133	0	0	5	10	15	20
93042412	18	6.5N	137.7E	30	32	26	13	49	94	219	0	0	5	10	15	25
93042418	19	6.8N	136.8E	30	53	49	84	124	166	283	0	0	10	10	15	25
93042500	20	6.9N	135.8E	30	91	102	128	162	182	274	0	0	10	10	20	20
93042506	21	7.0N	134.8E	30	29	43	91	127	149		0	5	10	10	20	
93042512	22	7.0N	134.0E	30	53	103	144	176	235		0	5	5	10	15	
93042518	23	7.0N	133.2E	25	72	120	160	203	271		0	0	5	5	15	
93042600	24	7.0N	132.5E	25	35	25	13	38	67		0	0	0	10	10	

TROPICAL DEPRESSION 04W (CONTINUED)

93042606	25	7.0N	131.8E	25	24	24	21	59			0	0	0	5		
93042612	26	7.0N	131.1E	25	24	34	83	115			0	0	5	5		
93042618	27	7.0N	130.4E	25	13	56	102				0	0	5			
93042700	28	7.0N	129.5E	25	13	42	65				0	5	5			
93042706	29	6.9N	128.6E	25	13	34					0	5				
93042712	30	6.7N	127.8E	20	32	61					5	5				
93042718	31	6.6N	127.0E	20	48						0					
			AVERAGE		37	68	101	131	162	216	1	3	5	7	12	17
			# CASES		31	30	28	26	24	20	31	30	28	26	24	20

TROPICAL STORM JACK (05W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93051700	1	11.0N	158.9E	25	13	85	145	210	289	587	0	5	5	10	5	-10
93051706	2	11.3N	159.2E	25	8	66	126	194	301		0	0	5	10	0	
93051712	3	11.5N	159.6E	25	21	60	117	211	313		0	0	5	10	0	
93051718	4	11.7N	159.7E	30	11	38	113	196	293		0	5	10	5	0	
93051800	5	12.0N	159.6E	30	11	50	111	179	289		0	5	10	5	-5	
93051806	6	12.2N	159.4E	30	18	81	142	234	385		5	10	10	5	-10	
93051812	7	12.4N	158.9E	30	59	126	218	363	570		5	0	0	-10	-15	
93051818*	8	12.4N	158.3E	30	5	8	18	53			0	0	-5	-15		
93051906*	9	12.5N	157.2E	30	13	26	71	118			0	0	-5	-5		
93051918	10	12.5N	155.9E	30	16	74	100	106	168	364	0	0	-5	0	0	5
93052000	11	12.5N	155.2E	35	18	71	53	83	133		0	0	0	0	5	
93052006	12	12.3N	154.3E	35	18	16	48	68	66		0	0	0	5	0	
93052012	13	12.3N	153.3E	35	5	54	115	108	104		-5	-5	0	5	5	
93052018	14	12.8N	152.5E	35	13	54	72	79	123		-5	0	5	5	10	
93052100	15	13.5N	151.9E	35	16	30	42	120			-5	0	5	10		
93052106	16	14.2N	151.2E	30	5	75	195	348			-5	0	0	0		
93052112*	17	14.9N	150.4E	30	23	120					-5	-5				
93052200**	18	15.2N	148.4E	25	18	31					5	10				
93052206	19	15.2N	147.3E	25	23	50					0	5				
93052218	20	15.0N	145.3E	20	18						0					
			AVERAGE		17	59	106	167	253	476	2	3	4	6	5	8
			# CASES		20	19	16	16	12	2	20	19	16	16	12	2

* TD Warning Issued

** Regenerated Warning

SUPER TYPHOON KORYN (06W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93061518	1	4.9N	156.7E	25	55	95	143	185	198	113	0	5	5	5	10	15
93061600	2	5.1N	156.6E	25	64	109	157	191	169	60	0	0	0	5	10	15
93061606	3	5.3N	156.5E	25	78	126	173	181	140	64	5	5	5	10	10	15
93061612	4	5.6N	156.4E	30	68	114	148	129	93	117	0	0	5	10	10	15
93061618	5	6.0N	156.4E	30	64	109	123	102	106	184	0	0	5	10	10	15
93061700	6	6.5N	156.3E	35	5	25	77	151	240	332	0	0	5	5	10	15
93061706	7	7.0N	156.1E	35	8	48	117	189	263	330	0	5	5	10	10	15
93061712	8	7.4N	155.8E	35	8	64	131	206	278	321	0	5	5	10	10	15
93061718	9	7.5N	155.3E	35	30	77	129	192	250	280	0	0	5	5	10	15
93061800	10	7.6N	154.6E	35	8	43	114	173	196	201	0	0	0	0	0	10
93061806	11	7.6N	153.8E	35	30	60	96	131	144	166	0	0	0	0	0	10
93061812	12	7.6N	152.9E	35	25	49	93	134	168	186	0	0	5	10	10	5
93061818	13	7.6N	151.8E	35	13	59	135	185	228	177	0	0	5	10	10	0
93061900	14	7.5N	150.8E	35	17	56	72	96	107	0	0	5	10	10	15	5
93061906	15	7.4N	149.8E	35	13	42	98	139	149	115	0	0	5	10	15	0

SUPER TYPHOON KORYN (06W) (CONTINUED)

93061912	16	7.2N	148.9E	35	18	63	125	146	125	53	0	5	10	10	5	-10
93061918	17	7.0N	148.1E	35	46	112	167	173	114	78	0	5	10	10	0	-15
93062000	18	6.9N	147.6E	35	72	137	162	148	117	119	0	0	5	5	-5	-30
93062006	19	7.0N	147.1E	35	62	78	86	120	164	218	0	0	5	0	-10	-45
93062012	20	7.0N	146.6E	35	69	82	96	148	174	248	0	0	0	-5	-15	-60
93062018	21	7.2N	145.8E	35	98	106	94	120	138	206	0	0	-5	-10	-20	-70
93062100	22	7.5N	145.1E	35	107	94	90	90	112	138	0	-5	-10	-15	-30	-80
93062106	23	8.0N	144.1E	35	99	81	91	109	134	187	0	-10	-15	-25	-45	-85
93062112	24	8.5N	142.9E	40	84	104	134	176	189	225	-5	-10	-20	-30	-60	-80
93062118	25	9.3N	141.4E	45	90	112	148	181	203	258	0	-10	-20	-40	-60	-75
93062200	26	9.8N	140.1E	50	46	106	146	169	204	279	0	-5	-20	-50	-65	-60
93062206	27	10.3N	139.0E	55	47	89	130	159	201	287	0	-10	-35	-55	-70	-55
93062212	28	10.7N	137.9E	60	45	61	68	105	135	229	-5	-20	-50	-65	-70	-50
93062218	29	11.2N	136.8E	65	11	21	29	71	104	219	-5	-25	-50	-65	-60	-40
93062300	30	11.8N	135.3E	75	13	26	24	51	95	240	0	-20	-30	-25	-15	5
93062306	31	12.2N	134.3E	90	13	31	70	111	161	286	0	-15	-20	-15	-5	20
93062312	32	12.7N	133.2E	105	13	50	105	159	224	423	0	-10	-15	-10	0	25
93062318	33	13.1N	132.0E	115	13	62	87	132	202	413	0	-10	-10	0	10	35
93062400	34	13.4N	130.8E	125	5	21	31	46	108	281	0	-5	5	10	15	10
93062406	35	13.6N	129.6E	130	8	18	30	47	108	289	0	5	10	15	10	-5
93062412	36	14.0N	128.5E	130	18	29	63	129	213	418	0	5	10	15	10	-5
93062418	37	14.4N	127.4E	130	0	8	33	111	202	452	0	5	10	10	-10	10
93062500	38	14.9N	126.3E	125	8	30	70	140	228	471	-5	-15	-15	-10	-10	25
93062506	39	15.5N	125.0E	120	18	37	82	161	258	580	-5	-5	0	-10	-5	40
93062512	40	16.2N	123.9E	115	8	58	136	242	340	695	-10	0	-10	-5	0	60
93062518	41	16.8N	122.6E	110	12	85	169	269	388		5	5	0	5	5	
93062600	42	17.5N	121.2E	105	18	52	135	235	418		0	0	5	-5	0	
93062606	43	18.2N	119.8E	90	33	85	175	307	511		0	15	20	5	15	
93062612	44	18.9N	118.4E	90	11	86	162	320	495		0	10	5	20	35	
93062618	45	19.5N	116.8E	90	0	33	120	309			0	-5	-10	-10		
93062700	46	20.0N	115.3E	90	0	35	160	311			0	-5	5	10		
93062706	47	20.7N	113.9E	85	13	62	221				0	0	0			
93062712	48	21.4N	112.4E	85	5	131	268				0	5	10			
93062718	49	21.5N	110.7E	80	39	191					0	0				
93062800	50	21.5N	108.9E	65	72	173					-15	5				
93062806	51	21.4N	106.7E	50	72						5					
			AVERAGE		35	73	115	161	200	249	1	6	11	15	18	29
			# CASES		51	50	48	46	44	40	51	50	48	46	44	40

TROPICAL DEPRESSION 07W

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93061706	1	9.4N	130.1E	25	13	32	54	91	152		0	0	-5	0	5	
93061712	2	9.8N	129.8E	25	13	41	94	200	297		0	0	-5	5	5	
93061718	3	10.3N	129.4E	25	18	50	131	229	357		0	-5	-5	0	10	
93061800	4	10.7N	128.8E	25	37	69	152	268	385		0	-5	5	5	5	
93061806	5	11.2N	128.0E	30	16	21	103	210			0	5	10	15		
93061812	6	11.7N	127.2E	30	18	79	161	247			0	10	10	10		
93061818	7	12.2N	126.0E	30	8	52	136				0	5	10			
93061900	8	12.7N	124.7E	25	44	131	219				5	5	5			
93061906	9	13.3N	123.4E	25	60	136					5	5				
93061912	10	13.9N	122.0E	25	29	58					0	0				
93061918	11	14.6N	120.6E	20	29						0					
93062000	12	15.2N	119.2E	20	50						0					
			AVERAGE		29	68	132	208	298		1	4	7	6	6	
			# CASES		12	10	8	6	4		12	10	8	6	4	

TYPHOON LEWIS (08W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93070700	1	10.0N	128.3E	30	58	103	108	92	72	172	0	5	0	-5	-15	-25
93070706	2	10.7N	127.8E	30	21	35	17	46	99	231	0	5	5	0	-10	-10
93070712	3	11.3N	127.1E	30	13	35	111	205	295	475	0	0	-5	-15	-30	-35
93070718	4	11.8N	126.3E	30	17	76	175	272	355	513	0	0	-10	-20	-35	-30
93070800	5	12.2N	125.2E	35	13	50	118	193	262	343	-5	-10	-20	-30	-40	-20
93070806	6	12.7N	124.0E	35	13	59	107	161	220	236	-5	-10	-20	-25	-35	0
93070812	7	13.2N	122.4E	40	44	116	193	252	307	309	-5	-15	-25	-35	-35	5
93070818	8	13.6N	120.8E	45	77	143	196	276	320	314	-10	-15	-15	-25	-10	25
93070900	9	14.3N	119.3E	50	88	150	203	263	286	259	-15	-25	-30	-30	-10	30
93070906	10	15.2N	117.9E	55	16	26	30	74	121	194	-5	-5	-10	-20	-15	10
93070912	11	15.9N	116.4E	60	18	58	102	128	130	222	-5	-10	-10	-15	-10	15
93070918	12	16.6N	114.9E	65	12	18	57	101	168	266	-10	-20	-15	-15	-10	10
93071000	13	17.3N	113.5E	75	8	36	94	150	186	289	-10	-10	-15	-10	0	15
93071006	14	18.0N	112.0E	85	11	72	151	180	210		-5	-5	-10	0	10	
93071012	15	18.3N	110.5E	85	6	55	113	169	222		0	0	-5	0	0	
93071018	16	18.4N	109.2E	80	24	75	117	169	205		0	15	10	10	5	
93071100	17	18.5N	108.0E	75	0	57	90	111	126		0	0	5	5	10	
93071106	18	18.6N	107.2E	70	11	40	54	45			0	5	10	5		
93071112	19	18.7N	106.5E	65	16	38	37	30			-10	0	5	5		
93071118	20	18.8N	105.9E	55	18	24	41				0	15	15			
93071200	21	18.9N	105.3E	45	18	76	140				0	10	5			
93071206	22	19.0N	104.6E	35	18	53					5	5				
93071212	23	19.0N	103.8E	30	23	23					-5	0				
			AVERAGE		24	62	108	154	211	295	4	8	12	14	16	18
			# CASES		23	23	21	19	17	13	23	23	21	19	17	13

TROPICAL STORM MARIAN (09W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93071312	1	8.4N	137.1E	25	85	163	252	334	377	452	-5	-5	-5	0	20	50
93071318	2	8.8N	135.8E	30	51	104	186	246	276	385	0	0	0	15	35	40
93071400	3	9.5N	134.5E	35	18	55	108	125	144	294	0	5	15	35	45	40
93071406	4	10.3N	133.2E	35	21	76	104	121	146	334	0	0	20	40	45	45
93071412	5	11.3N	132.1E	40	16	26	59	98	85		-5	0	20	35	50	
93071418	6	12.4N	131.1E	45	18	8	23	51	37		0	15	35	45	60	
93071500	7	13.4N	130.1E	45	34	72	96	100	156		0	20	35	50	60	
93071506	8	14.1N	129.0E	40	37	53	59	86	159		0	15	25	40	55	
93071512	9	14.7N	128.0E	35	45	46	46	105			-10	0	10	10		
93071518	10	15.3N	126.9E	30	49	33	83	161			-5	0	10	15		
93071600	11	15.9N	125.8E	30	40	100	202				0	5	0			
93071606	12	16.6N	124.9E	30	71	170	267				0	0	5			
93071612	13	17.6N	124.4E	25	160	297					0	0				
93071618	14	18.4N	124.1E	25	115	226					0	5				
93071700	15	19.3N	123.8E	25	29						0					
93071706	16	20.1N	123.6E	20	6						0					
			AVERAGE		50	103	124	143	173	367	2	5	15	29	46	44
			# CASES		16	14	12	10	8	4	16	14	12	10	8	4

TYPHOON NATHAN (10W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93071912	1	14.0N	149.9E	30	38	80	124	170	223	268	-5	-5	-5	0	10	25
93071918	2	14.6N	149.1E	30	24	50	83	124	157	149	0	-5	0	10	20	35
93072000	3	15.2N	148.2E	35	45	74	112	136	162	148	0	5	10	20	30	40

TYPHOON NATHAN (10W) (CONTINUED)

93072006	4	15.7N	147.2E	40	29	38	54	54	55	155	0	5	10	20	30	40
93072012	5	16.2N	146.2E	40	34	46	66	84	108	227	5	10	20	30	40	35
93072018	6	16.7N	145.2E	45	37	55	83	109	139	279	5	15	25	35	40	40
93072100	7	17.3N	144.2E	45	13	13	24	73	127	54	0	5	15	25	25	15
93072106	8	18.0N	143.3E	45	21	43	58	121	204	140	0	5	15	20	20	-5
93072112	9	18.7N	142.4E	45	20	45	94	158	219	149	0	5	10	15	10	-10
93072118	10	19.4N	141.5E	45	33	78	154	219	228	243	0	0	0	10	5	0
93072200	11	20.1N	140.9E	45	33	85	158	229	176	393	0	5	5	0	-5	0
93072206	12	20.9N	140.5E	45	12	78	156	188	161	540	0	0	5	0	-20	10
93072212	13	21.4N	140.3E	45	8	58	99	43	191	513	0	0	0	-5	-20	15
93072218	14	21.9N	140.1E	50	18	42	18	127	305		0	5	5	-10	0	
93072300	15	22.4N	139.9E	50	11	22	126	338	511		0	0	0	-10	15	
93072306	16	22.9N	139.8E	50	18	66	249	440	541		0	0	-10	0	20	
93072312	17	23.6N	139.7E	55	18	154	386	565	584		0	0	-10	10	25	
93072318	18	25.1N	139.4E	55	6	105	216	255			0	-5	5	25		
93072400	19	27.2N	138.7E	60	30	128	203	172			0	-5	20	20		
93072406	20	29.7N	137.9E	70	5	81	158				0	15	20			
93072412	21	32.2N	136.4E	70	10	168	214				0	5	25			
93072418	22	34.2N	134.7E	55	6	96					0	20				
93072500	23	36.0N	133.1E	45	5	11					0	10				
93072506	24	37.5N	132.7E	30	5						0					
93072512	25	38.7N	133.0E	25	34						0					
			AVERAGE		21	71	135	190	241	251	1	6	10	14	20	21
			# CASES		25	23	21	19	17	13	25	23	21	19	17	13

TROPICAL STORM OFELIA (11W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93072506	1	20.3N	137.3E	30	23	82	177	247	234	138	5	10	20	10	-5	0
93072512	2	21.9N	136.5E	35	44	99	203	255	169		0	5	20	10	0	
93072518	3	23.2N	135.5E	40	37	85	158	138	29		0	5	15	0	5	
93072600	4	24.5N	134.2E	45	16	42	23	98	118		0	10	15	0	5	
93072606	5	25.5N	133.1E	45	8	27	78	219	83		0	10	10	5	5	
93072612	6	26.9N	132.4E	45	39	127	293	347			0	5	10	0		
93072618	7	28.6N	131.6E	45	18	85	265	194			0	5	5	5		
93072700	8	30.6N	131.2E	45	12	103	110				0	-10	-5			
93072706	9	32.8N	131.5E	45	5	65	43				-5	0	0			
93072712	10	35.8N	132.6E	40	20	36					5	10				
93072718	11	38.6N	133.8E	30	42	294					10	10				
93072800	12	40.2N	134.0E	30	117						0					
			AVERAGE		32	96	151	215	127	138	2	7	11	4	4	0
			# CASES		12	11	9	7	5	1	12	11	9	7	5	1

TYPHOON PERCY (12W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93072718	1	22.0N	128.9E	30	58	126	138	164	282		-5	0	0	-5	5	
93072800	2	23.3N	128.9E	30	8	24	49	26	166		0	-5	-10	-10	0	
93072806	3	24.4N	128.9E	35	18	73	90	40	146		0	0	-5	-10	-5	
93072812	4	25.4N	128.7E	40	24	43	51	182	266		0	-10	-10	-5	0	
93072818	5	26.5N	128.7E	45	16	79	224	382			5	-5	5	15		
93072900	6	27.7N	128.8E	55	32	127	307	417			0	0	10	10		
93072906	7	29.5N	129.1E	60	20	62	172				10	20	15			
93072912	8	31.7N	129.7E	65	19	94	153				10	5	5			
93072918	9	34.3N	130.6E	60	19	47					0	0				
93073000	10	37.0N	132.1E	55	12	126					0	0				
93073006	11	39.4N	133.8E	50	55						0					

TYPHOON PERCY (12W) (CONTINUED)

93073012	12	41.4N	135.2E	45	23						0					
			AVERAGE		26	80	148	202	215		3	5	8	9	3	
			# CASES		12	10	8	6	4		12	10	8	6	4	

TYPHOON ROBYN (13W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93080112	1	7.4N	152.3E	25	37	83	109	171	232	118	0	-5	-15	-20	-15	-5
93080118	2	8.0N	151.1E	25	70	98	136	195	208	71	0	-5	-10	-5	0	10
93080200	3	8.7N	149.9E	30	40	31	61	96	84	188	0	-10	-10	-5	0	20
93080206	4	9.1N	148.7E	35	17	72	125	209	318	563	0	-5	0	5	5	35
93080212	5	9.4N	147.5E	45	35	86	134	219	303	418	0	0	0	5	15	40
93080218	6	9.6N	146.2E	50	47	79	157	278	363	461	0	5	5	5	20	45
93080300	7	9.8N	144.9E	55	31	39	112	195	276	384	5	10	15	25	45	60
93080306	8	10.0N	143.6E	55	71	147	253	364	448	565	10	15	15	25	45	60
93080312	9	10.2N	142.5E	60	30	106	192	281	341	437	5	10	15	30	35	35
93080318	10	10.4N	141.9E	60	13	48	101	151	226	344	5	5	15	30	35	25
93080400	11	10.7N	141.5E	65	25	83	148	179	221	219	0	0	15	20	30	5
93080406	12	11.1N	141.0E	70	26	54	92	136	157	198	0	5	15	20	30	-5
93080412	13	11.5N	140.7E	70	16	24	30	49	79	151	0	10	10	20	15	-10
93080418	14	12.0N	140.3E	70	0	0	26	54	83	163	0	10	15	25	10	-10
93080500	15	12.5N	139.9E	65	29	109	166	212	245	249	5	0	5	5	-5	-10
93080506	16	13.2N	139.3E	65	26	35	60	99	123	121	0	-5	0	-15	-25	-10
93080512	17	14.1N	138.5E	70	29	44	76	110	131	169	0	5	-5	-15	-25	-5
93080518	18	15.0N	137.9E	70	35	64	88	122	142	194	0	5	-15	-25	-25	0
93080600	19	15.9N	137.2E	70	13	37	54	68	67	109	-5	-15	-25	-30	-25	5
93080606	20	16.6N	136.3E	70	0	11	28	41	55	118	0	-20	-35	-30	-20	5
93080612	21	17.4N	135.4E	85	0	17	24	50	58	150	0	-10	-15	-5	-5	0
93080618	22	18.4N	134.5E	95	6	5	21	39	60	187	0	-10	-5	0	0	5
93080700	23	19.3N	133.5E	105	6	30	28	33	49	199	0	-5	-5	0	0	15
93080706	24	20.1N	132.6E	115	12	29	53	57	99	331	-5	-5	0	5	10	20
93080712	25	21.0N	131.9E	120	24	69	90	107	166	489	-5	-5	0	5	5	25
93080718	26	22.1N	131.3E	120	16	40	47	89	177	460	-5	0	5	10	10	35
93080800	27	23.2N	130.8E	120	5	13	12	63	182		-5	5	10	10	20	
93080806	28	24.3N	130.3E	115	5	18	7	95	234		0	5	10	10	20	
93080812	29	25.3N	129.8E	110	5	20	80	207	379		5	10	10	15	20	
93080818	30	26.4N	129.4E	105	0	42	127	254	313		5	10	10	20	30	
93080900	31	27.6N	129.2E	100	8	12	12	20			0	-5	0	-5		
93080906	32	29.0N	129.1E	95	7	11	31	89			0	-5	-5	0		
93080912	33	30.5N	129.1E	95	13	20	12				0	5	5			
93080918	34	32.3N	129.3E	90	17	35	25				0	5	10			
93081000	35	34.2N	130.1E	80	6	60					0	5				
93081006	36	36.3N	131.2E	75	0	25					0	10				
93081012	37	38.4N	132.9E	65	6						0					
93081018	38	39.1N	133.9E	55	55						5					
			AVERAGE		21	48	80	136	194	272	2	7	10	14	18	19
			# CASES		38	36	34	32	30	26	38	36	34	32	30	26

TYPHOON STEVE (14W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93080600	1	12.9N	152.0E	25	13	8	34	71	113	197	0	0	0	5	10	10
93080606	2	13.4N	151.4E	25	13	33	62	72	105	194	0	0	0	5	10	5
93080612	3	13.9N	150.7E	30	29	72	120	164	236	314	-5	-5	-5	-5	-5	-5
93080618	4	14.3N	149.9E	30	70	130	169	207	266	347	-5	-10	-10	-10	-10	-5
93080700	5	14.6N	149.1E	35	24	13	13	60	102	284	0	5	10	15	20	30
93080706	6	14.7N	148.3E	40	18	33	23	54	72	234	0	5	5	10	15	25
93080712	7	15.0N	147.4E	40	18	13	36	78	144	285	5	5	5	10	15	25

TYPHOON STEVE (14W) (CONTINUED)

93080718	8	15.3N	146.5E	45	8	56	126	174	246	342	0	0	0	5	15	30
93080800	9	15.5N	145.6E	45	13	90	140	184	253	435	5	5	5	5	15	35
93080806	10	15.5N	144.7E	50	5	30	42	100	148	242	5	10	15	25	25	50
93080812	11	15.4N	143.7E	50	21	37	69	102	152	223	10	10	15	25	25	50
93080818	12	15.4N	142.8E	55	37	66	107	137	164	205	5	5	15	20	30	55
93080900	13	15.6N	141.9E	55	8	46	78	99	131	114	5	5	15	20	35	60
93080906	14	15.8N	141.1E	60	17	58	82	120	144	138	0	0	0	15	35	70
93080912	15	15.9N	140.3E	60	21	50	42	21	5	82	0	5	5	25	40	75
93080918	16	16.0N	139.5E	60	23	17	5	24	72	209	0	0	10	30	45	65
93081000	17	16.3N	138.6E	60	34	51	69	88	86	93	0	0	15	30	50	70
93081006	18	16.7N	137.7E	65	13	24	17	32	69		0	10	25	35	60	
93081012	19	17.1N	136.9E	65	12	8	54	113	193		0	15	25	40	60	
93081018	20	17.6N	136.2E	60	8	34	61	133	203		10	20	30	50	60	
93081100	21	18.2N	135.5E	55	13	45	84	152	201		0	10	25	50	65	
93081106	22	18.9N	134.9E	50	26	55	127	190			5	15	35	50		
93081112	23	19.6N	134.2E	50	26	66	127	161			0	15	35	45		
93081118	24	20.4N	133.4E	45	39	84	130				0	20	30			
93081200	25	21.3N	132.5E	40	11	36	69				-5	10	20			
93081206	26	22.3N	131.4E	30	11	27					0	5				
93081212	27	23.2N	130.3E	25	0	32					5	5				
93081218	28	23.9N	129.1E	25	5						0					
			AVERAGE		20	45	76	111	148	232	3	7	14	23	31	39
			# CASES		28	27	25	23	21	17	28	27	25	23	21	17

TROPICAL DEPRESSION 15W

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93081312	1	7.8N	175.9E	25	37	56	104				0	0	5			
93081318	2	8.4N	175.5E	25	41	71	110				0	5	15			
93081400	3	9.0N	175.2E	25	37	130					0	0				
93081406	4	9.6N	174.3E	25	45	119					0	5				
93081412	5	9.8N	173.0E	25	53						0					
93081418	6	9.8N	171.9E	20	11						0					
			AVERAGE		38	94	108				0	3	10			
			# CASES		6	4	2				6	4	2			

TYPHOON TASHA (16W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93081500*	1	9.4N	133.2E	25	91	225	327	396			0	0	0	-10		
93081506*	2	10.8N	131.2E	25	150	270	359	440			0	0	0	-5		
93081512*	3	12.5N	129.7E	25	151	168	188	194			0	-5	-10	-15		
93081518*	4	13.7N	128.7E	25	42	49	124	189			0	-5	-10	-15		
93081600	5	14.6N	128.0E	30	96	104	121	168	246	481	-5	-10	-10	-10	-15	-25
93081606	6	15.4N	127.2E	30	77	111	150	203	279	529	-5	-10	-10	-15	-15	-30
93081612	7	16.2N	126.4E	35	42	75	125	208	321	619	0	5	10	15	15	-10
93081618	8	16.9N	125.6E	35	29	39	30	61	151	418	0	5	5	5	10	-15
93081700	9	17.7N	124.9E	40	34	70	79	90	99	285	-5	-5	-5	-5	-5	-30
93081706	10	18.3N	124.1E	40	26	45	94	142	194	286	-5	-10	-15	-15	-20	-45
93081712	11	18.8N	123.2E	45	41	62	100	167	225	334	-5	-5	-5	-5	-10	-45
93081718	12	19.1N	122.2E	45	33	38	90	187	266	380	5	5	5	-5	-10	-45
93081800	13	19.3N	121.2E	50	18	49	106	169	198	284	0	0	0	-5	-20	-50
93081806	14	19.5N	120.2E	50	11	30	105	156	188	124	0	0	-5	-10	-45	-40
93081812	15	19.7N	119.1E	55	8	69	119	142	177	317	0	0	0	0	-10	-25
93081818	16	19.9N	118.0E	55	5	66	84	83	66		0	-5	0	-10	-30	
93081900	17	19.9N	116.9E	60	20	62	69	36	76		0	0	0	-15	-25	

* TD Warning Issued

TYPHOON TASHA (16W) (CONTINUED)

93081906	18	19.7N	116.0E	65	5	22	28	8	83		0	5	-5	-10	-15	
93081912	19	19.8N	115.2E	65	24	43	50	37	50		0	0	-10	-5	-10	
93081918	20	20.0N	114.5E	65	13	21	30	57	101		0	-10	-5	5	0	
93082000	21	20.2N	113.9E	70	21	39	55	84	166		0	-5	5	15	15	
93082006	22	20.6N	113.3E	80	8	22	83	150			0	5	0	0		
93082012	23	20.9N	112.6E	80	8	44	92	207			0	-10	-10	0		
93082018	24	21.3N	111.9E	75	18	61	130				0	0	0			
93082100	25	21.7N	111.0E	70	16	45	160				5	10	10			
93082106	26	22.1N	110.1E	60	23	65					5	5				
93082112	27	22.7N	109.3E	50	24	73					15	15				
93082118	28	23.3N	108.3E	40	39						10					
93082200	29	24.2N	106.6E	30	52						5					
			AVERAGE		39	73	117	156	170	369	2	5	5	8	16	33
			# CASES		29	27	25	23	17	11	29	27	25	23	17	11

TYPHOON KEONI (01C)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93082000	1	20.6N	179.1E	75	18	79	126	192	241	323	0	-10	-25	-35	-35	-20
93082006	2	21.2N	178.1E	80	6	37	94	139	181	256	-5	-15	-30	-35	-30	-15
93082012	3	21.9N	177.2E	85	11	49	67	80	89	114	0	-10	-25	-30	-25	-10
93082018	4	22.4N	176.0E	90	25	65	81	92	96	152	0	-15	-25	-25	-20	-10
93082100	5	23.1N	174.8E	95	18	60	86	107	106	60	-5	-15	-20	-20	-15	-10
93082106	6	23.8N	173.7E	100	20	48	80	117	104	73	-10	-15	-15	-15	-10	-10
93082112	7	24.6N	172.8E	100	10	40	67	146	294	574	-5	-5	-5	-5	-5	-15
93082118	8	25.3N	171.9E	100	20	43	71	189	340	556	-5	0	0	0	-5	-25
93082200	9	26.0N	171.1E	95	20	52	90	164	249	458	-5	5	5	5	-5	-25
93082206	10	26.7N	170.4E	90	20	26	101	204	291	492	-5	0	0	0	-5	-35
93082212	11	27.3N	169.9E	85	8	44	133	219	295	509	-5	0	5	0	-15	-30
93082218	12	28.0N	169.2E	80	29	139	273	358	415	632	-5	0	0	-5	-30	-30
93082300	13	28.3N	168.2E	75	5	48	100	112	101	191	0	5	0	-15	-30	-25
93082306	14	28.5N	167.1E	70	10	50	64	72	42	170	0	0	-5	-30	-35	-20
93082312	15	28.7N	165.9E	65	19	43	84	125	170	391	5	0	-10	-25	-20	5
93082318	16	28.9N	164.6E	65	18	84	170	255	356	536	5	0	-20	-25	-15	5
93082400	17	29.5N	163.5E	65	18	52	61	104	192		0	-10	-25	-25	-20	
93082406	18	30.2N	162.5E	65	5	26	78	224	336		0	-20	-25	-20	-10	
93082412	19	30.8N	161.8E	75	11	27	87	162	209	296	-5	-10	-10	-5	10	15
93082418	20	31.5N	161.1E	85	0	49	120	161	199	343	-5	5	0	5	10	15
93082500	21	31.9N	160.4E	85	30	107	172	199	227	418	0	10	5	15	15	20
93082506	22	32.2N	159.9E	85	27	86	137	184	203	441	0	10	15	15	20	20
93082512	23	32.3N	159.5E	80	5	27	98	115	166	420	-5	0	15	15	20	25
93082518	24	32.4N	159.2E	75	11	69	131	182	274	557	0	5	10	15	15	20
93082600	25	32.8N	159.1E	70	27	115	164	243	328	575	-5	15	15	20	20	20
93082606	26	33.7N	159.1E	60	20	31	60	86	182	425	0	10	15	15	15	20
93082612	27	34.5N	159.1E	50	38	66	108	119	178	326	5	0	5	5	5	0
93082618	28	35.1N	158.8E	50	20	61	37	43	128		-5	0	0	0	0	
93082700	29	35.6N	158.3E	45	12	48	115	201	291		0	5	10	10	0	
93082706	30	36.2N	158.3E	40	31	97	196	279			0	5	5	5		
93082712	31	36.8N	158.7E	35	5	72	173	262			0	5	5	0		
93082718	32	36.9N	159.4E	35	15	91	202				0	0	0			
93082800	33	37.0N	160.4E	30	23	72	121				0	5	0			
93082806	34	37.0N	161.6E	30	19	61					0	5				
93082812	35	36.5N	162.8E	25	20	83					0	-5				
			AVERAGE		17	62	114	166	217	372	3	6	11	14	16	18
			# CASES		35	35	33	31	29	25	35	35	33	31	29	25

TYPHOON VERNON (17W)

DTG	WRN NO.	BEST TRACK LAT	LONG	WIND	POSITION ERRORS 00	12	24	36	48	72	WIND ERRORS 00	12	24	36	48	72
93082112*	1	17.8N	152.9E	25	24	55	61	68			0	-10	-15	-20		
93082200	2	19.7N	153.3E	35	58	137	201	213	216	155	0	0	5	0	0	-5
93082206	3	20.3N	152.9E	35	26	85	115	108	78	43	0	0	0	-5	-5	-5
93082212	4	20.6N	152.5E	40	20	55	65	53	29	155	-5	-5	-5	-10	-10	-5
93082218	5	20.8N	152.0E	40	17	33	76	127	176	282	-5	-10	-10	-15	-15	0
93082300	6	21.1N	151.6E	45	16	55	107	181	253	337	0	-5	-5	0	0	15
93082306	7	21.5N	151.0E	50	20	54	126	222	296	416	-5	-5	-5	0	5	15
93082312	8	22.2N	150.5E	55	16	43	120	182	252	374	0	0	10	25	40	45
93082318	9	22.8N	150.0E	60	30	84	160	212	251	429	0	0	10	30	45	45
93082400	10	23.5N	149.4E	65	24	71	109	169	207	367	0	0	5	10	20	30
93082406	11	24.3N	148.8E	70	17	22	24	83	109	363	0	0	5	15	20	30
93082412	12	25.2N	148.3E	75	13	58	125	127	95	451	0	5	15	25	30	40
93082418	13	26.1N	147.5E	80	18	48	89	75	132	568	0	5	20	25	30	45
93082500	14	26.8N	146.4E	80	20	51	62	54	173	664	0	5	20	25	35	40
93082506	15	27.7N	145.2E	80	13	7	70	134	156		0	10	20	20	-5	
93082512	16	28.5N	143.9E	80	7	36	113	184	273		5	10	20	25	-10	
93082518	17	29.1N	142.7E	75	5	64	151	211	291		10	10	20	20	-10	
93082600	18	29.7N	141.7E	75	13	108	199	271	395		10	15	25	10	-5	
93082606	19	30.4N	141.0E	75	21	91	143	234			10	15	20	0		
93082612	20	31.4N	140.8E	75	7	48	151	346			5	10	15	0		
93082618	21	32.6N	140.6E	75	7	20	45				0	-5	-5			
93082700	22	34.0N	140.6E	70	5	22	57				0	-5	-10			
93082706	23	35.6N	140.9E	70	7	23					5	5				
93082712	24	37.2N	141.6E	65	11	50					0	0				
93082718	25	38.9N	142.5E	60	12						0					
93082800	26	41.8N	144.1E	55	14						0					
			AVERAGE		18	56	108	163	199	355	2	6	12	14	17	25
			# CASES		26	24	22	20	17	13	26	24	22	20	17	13

* TD Warning Issued

TROPICAL STORM WINONA (18W)

DTG	WRN NO.	BEST TRACK LAT	LONG	WIND	POSITION ERRORS 00	12	24	36	48	72	WIND ERRORS 00	12	24	36	48	72
93082206	1	11.6N	123.8E	25	13	30	41	34	29	117	0	-5	-5	0	5	20
93082212	2	11.7N	122.7E	25	11	35	48	11	71	171	0	-5	-5	0	5	20
93082218	3	11.6N	121.7E	30	26	67	70	80	117	192	0	0	0	5	15	25
93082300	4	11.6N	120.6E	30	5	21	87	176	250	313	0	0	0	5	15	30
93082306	5	11.8N	119.6E	35	16	48	140	223	281	325	0	0	0	10	20	35
93082312	6	12.0N	118.9E	35	16	78	168	256	314	370	5	5	5	10	20	35
93082318	7	12.6N	118.1E	40	30	119	210	285	333	386	0	0	5	10	20	30
93082400	8	13.4N	117.4E	40	48	121	183	223	254	245	0	0	5	10	15	25
93082406	9	14.3N	116.9E	45	13	34	83	113	149	206	0	5	10	15	25	25
93082412	10	15.1N	116.5E	45	18	71	128	200	257	278	0	0	0	5	20	20
93082418	11	15.8N	116.3E	45	24	49	97	156	194	207	0	0	0	10	10	5
93082500	12	16.4N	116.2E	45	6	72	149	235	315	424	0	0	0	10	0	-10
93082506	13	16.9N	116.1E	45	16	79	127	166	205	297	0	0	10	10	10	0
93082512	14	17.1N	116.0E	45	13	45	92	115	165	286	-5	-5	0	-5	-5	-10
93082518	15	17.3N	115.9E	45	16	45	64	97	162	299	-5	0	-5	-5	-5	-5
93082600	16	17.5N	115.8E	45	29	55	72	126	199	284	-5	0	-5	-10	-10	-10
93082606	17	17.6N	115.7E	40	8	24	66	132	206	312	-5	-10	-10	-15	-15	-5
93082612	18	17.7N	115.5E	40	12	51	114	183	261	415	-5	-10	-10	-15	-15	0
93082618	19	17.8N	115.1E	45	25	68	136	209	270		-5	-10	-10	-15	-10	
93082700	20	17.8N	114.6E	45	18	70	121	178	220		-5	-10	-10	-15	-10	
93082706	21	17.7N	113.9E	45	23	65	122	183	234		-5	-10	-10	-10	-5	
93082712	22	17.5N	113.1E	45	0	30	58	70	121		-5	-5	-10	-5	5	

TROPICAL STORM WINONA (18W) (CONTINUED)

93082718	23	17.3N	112.4E	45	12	41	64	82			0	-5	-5	0		
93082800	24	17.1N	111.6E	45	8	23	75	146			0	-5	-5	0		
93082806	25	16.9N	110.8E	45	5	5	61				0	5	10			
93082812	26	16.8N	109.9E	45	12	43	107				0	5	5			
93082818	27	16.9N	108.9E	40	31	93					0	0				
93082900	28	17.4N	108.0E	40	30	78					0	0				
93082906	29	18.0N	107.1E	35	13						0					
93082912	30	18.5N	106.2E	30	6						0					
			AVERAGE		17	56	104	154	210	285	2	4	5	8	12	17
			# CASES		30	28	26	24	22	18	30	28	26	24	22	18

SUPER TYPHOON YANCY (19W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93082906	1	20.0N	136.8E	30	11	11	49	25	173	257	-5	0	0	5	0	-15
93082912	2	20.0N	135.7E	30	28	98	112	32	113	235	0	5	10	15	15	-20
93082918	3	20.3N	134.8E	30	45	104	75	45	90	181	0	0	0	0	5	-25
93083000	4	20.9N	134.2E	30	30	73	61	90	93	150	0	0	-5	-5	-5	-35
93083006	5	21.5N	133.2E	35	13	65	172	192	217	287	0	0	-10	-10	-20	-50
93083012	6	22.0N	131.9E	35	0	126	177	174	195	204	0	-5	-15	-20	-30	-45
93083018	7	21.8N	130.4E	40	71	18	62	121	90	146	0	-5	-5	-20	-25	-30
93083100	8	21.1N	129.2E	45	37	28	53	45	67	142	0	-10	-15	-30	-35	-30
93083106	9	20.7N	128.1E	55	13	30	75	58	94	218	0	0	-15	-20	-35	-15
93083112	10	21.0N	127.3E	60	8	50	108	186	301	594	0	-10	-25	-30	-30	-10
93083118	11	21.5N	126.7E	65	36	63	84	104	125	286	0	-15	-20	-40	-25	25
93090100	12	22.1N	126.1E	75	12	13	42	113	188	417	0	-10	-10	-15	-5	50
93090106	13	22.7N	125.7E	90	5	44	93	141	180	308	0	0	-10	0	0	60
93090112	14	23.3N	125.4E	100	5	27	86	120	141	146	0	-5	-10	-15	-20	20
93090118	15	24.0N	125.4E	105	6	41	97	156	177		0	-15	-10	-15	5	
93090200	16	24.9N	125.7E	115	6	27	67	112	154		0	0	-5	-10	25	
93090206	17	25.9N	126.3E	130	0	31	78	98	108		0	20	20	25	35	
93090212	18	27.0N	127.1E	125	6	20	15	55	278		0	-5	-15	15	10	
93090218	19	28.1N	127.9E	120	6	11	30	112			0	-5	20	25		
93090300	20	29.4N	129.0E	120	11	27	108	77			0	0	40	30		
93090306	21	30.9N	130.3E	115	6	52	113				0	30	45			
93090312	22	32.7N	131.8E	110	7	72	86				0	40	35			
93090318	23	34.7N	133.7E	75	13	108					10	25				
93090400	24	37.2N	136.0E	55	33	427					0	5				
93090406	25	39.3N	137.4E	45	63						0					
93090412	26	40.6N	137.6E	40	20						0					
			AVERAGE		19	66	84	103	155	255	1	9	15	17	18	31
			# CASES		26	24	22	20	18	14	26	24	22	20	18	14

TROPICAL STORM ZOLA (20W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93090512	1	19.1N	129.7E	25	28	71	78	33	20	114	0	5	10	15	25	50
93090518	2	19.4N	129.0E	25	18	39	69	112	158	255	0	5	5	10	25	45
93090600	3	19.8N	128.4E	30	24	103	246	385	457	588	0	5	10	15	30	60
93090606	4	20.5N	128.0E	30	13	23	71	108	138	259	0	0	5	15	30	75
93090612	5	21.3N	127.8E	35	24	40	93	111	106	212	0	5	15	30	35	65
93090618	6	22.3N	128.2E	40	8	65	124	151	174	296	0	5	20	35	35	60
93090700	7	23.3N	128.7E	40	25	92	151	156	204		0	5	20	30	50	
93090706	8	24.3N	129.4E	45	44	96	132	181	240		0	5	20	25	65	
93090712	9	25.5N	130.2E	45	0	12	54	56	48		0	5	10	30	40	
93090718	10	26.8N	131.0E	45	18	62	98	103	101		0	5	0	35	20	
93090800	11	28.2N	131.8E	45	12	67	64	49			0	0	20	20		

TROPICAL STORM ZOLA (20W) (CONTINUED)

93090806	12	29.7N	132.4E	45	24	51	48	55			0	-5	30	20		
93090812	13	31.2N	133.2E	50	30	7	4				-5	10	20			
93090818	14	32.9N	134.3E	55	23	25	18				0	20	5			
93090900	15	34.4N	136.5E	40	23	90					5	15				
93090906	16	35.7N	138.3E	25	20	26					0	-5				
			AVERAGE		21	55	90	125	165	288	1	6	14	23	36	59
			# CASES		16	16	14	12	10	6	16	16	14	12	10	6

TYPHOON ABE (21W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93090900	1	18.4N	123.3E	25	8	16	58	159	269	565	0	0	-5	-10	-15	-15
93090906	2	18.9N	123.7E	30	47	111	187	310	409	701	0	0	-5	-5	-15	-10
93090912	3	19.2N	123.7E	30	33	70	164	253	359	634	0	-5	-10	-15	-15	-15
93090918	4	19.5N	123.8E	35	16	41	127	196	305	524	0	-5	-5	-15	-10	-10
93091000	5	19.8N	123.9E	40	12	63	118	204	323	541	0	-5	-10	-10	-10	-15
93091006	6	19.9N	123.9E	50	32	109	162	261	382	570	0	5	0	5	5	0
93091012	7	19.9N	123.6E	55	49	104	186	301	422	591	0	0	0	0	0	0
93091018	8	20.0N	123.3E	60	54	99	195	310	418	597	0	-5	0	0	5	10
93091100	9	20.3N	123.0E	70	5	61	140	224	308	582	0	10	15	15	15	35
93091106	10	20.6N	122.6E	80	17	81	154	221	283	550	0	5	5	0	-10	35
93091112	11	20.8N	122.0E	80	11	73	159	232	340	665	0	0	-10	-5	-10	60
93091118	12	20.9N	121.3E	85	8	18	68	96	126	161	-5	-20	-30	-50	-50	10
93091200	13	21.0N	120.6E	90	8	5	33	76	105	92	0	-5	-5	-10	5	25
93091206	14	21.1N	119.9E	95	8	28	86	124	116		-5	-5	-10	0	20	
93091212	15	21.2N	119.2E	100	6	41	81	97	81		-5	-5	-10	5	45	
93091218	16	21.5N	118.7E	100	13	45	72	73	72		0	-10	-5	20	35	
93091300	17	21.9N	118.3E	105	12	51	56	16	16		-5	-15	0	10	10	
93091306	18	22.2N	118.0E	110	8	8	49	98			0	0	15	30		
93091312	19	22.4N	117.6E	110	8	38	104	163			-10	0	25	20		
93091318	20	22.7N	117.0E	100	6	32	89				-10	15	40			
93091400	21	23.1N	116.3E	90	13	44	97				0	35	40			
93091406	22	23.4N	115.3E	70	8	28					5	20				
93091412	23	23.7N	114.3E	45	17	10					10	25				
93091418	24	24.2N	113.2E	25	13						10					
93091500	25	24.7N	112.3E	20	12						0					
			AVERAGE		17	52	114	180	255	522	3	8	12	12	16	18
			# CASES		25	23	21	19	17	13	25	23	21	19	17	13

TYPHOON BECKY (22W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93091418	1	17.4N	125.5E	25	62	61	49	83	184	353	5	0	-10	-10	-10	25
93091500	2	17.9N	124.5E	30	45	12	34	52	105	154	0	-5	-10	-15	-5	35
93091506	3	18.3N	123.3E	35	11	21	54	84	122	154	0	-5	-10	-10	10	30
93091512	4	18.5N	122.2E	40	30	66	86	140	171	151	-5	-10	-15	-5	15	30
93091518	5	18.8N	121.0E	45	12	46	85	145	165	137	-5	-10	-10	10	25	20
93091600	6	18.9N	119.7E	50	18	62	130	167	168		-5	-5	5	20	25	
93091606	7	19.4N	118.3E	55	23	62	123	159	162		0	0	15	25	20	
93091612	8	20.1N	116.9E	60	41	94	143	150	133		-5	5	20	25	15	
93091618	9	20.8N	115.3E	65	8	36	77	73	52		0	15	20	20	5	
93091700	10	21.5N	113.7E	60	0	52	102	155			0	-5	10	0		
93091706	11	22.1N	112.2E	55	6	34	58				0	5	10			
93091712	12	22.7N	110.7E	50	8	55	93				0	5	0			
93091718	13	23.2N	109.4E	40	12	49					5	10				
			AVERAGE		22	50	86	121	141	191	2	6	11	14	14	28

TYPHOON CECIL (23W)

			# CASES		13	13	12	10	9	5	13	13	12	10	9	5
	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93092218	1	14.0N	151.1E	25	87	169	273	373	430	562	0	0	5	5	0	-25
93092300	2	13.9N	150.5E	30	48	92	151	213	306	532	5	10	15	10	-5	-15
93092306	3	13.8N	150.0E	30	29	60	120	202	326	556	5	10	10	0	-15	-15
93092312	4	13.9N	149.5E	35	5	53	153	295	410	604	0	5	0	-15	-20	-15
93092318	5	14.1N	149.2E	35	18	108	228	366	468	670	5	0	-10	-25	-25	-10
93092400	6	14.8N	149.0E	40	37	124	271	381	456	753	0	-10	-25	-30	-25	10
93092406	7	15.7N	148.5E	45	30	120	263	368	461	901	0	-15	-30	-30	-20	20
93092412	8	16.7N	147.9E	55	37	77	121	155	230	690	0	-10	-10	-5	5	25
93092418	9	17.9N	147.1E	65	0	48	81	119	219	679	0	-10	-5	10	10	20
93092500	10	19.3N	146.3E	80	13	32	52	130	287		0	-5	0	10	30	
93092506	11	20.6N	145.6E	90	5	40	74	112	255		0	0	15	15	30	
93092512	12	21.8N	145.0E	95	13	29	77	153	252		0	10	5	20	5	
93092518	13	22.8N	144.7E	100	20	49	107	182	238		0	10	5	10	0	
93092600	14	23.8N	144.7E	100	17	72	147	180			0	5	20	5		
93092606	15	24.8N	145.0E	100	20	70	205	339			0	0	10	5		
93092612	16	25.9N	145.7E	100	13	53	106				0	10	-5			
93092618	17	27.0N	146.9E	95	6	66	135				0	5	-5			
93092700	18	28.8N	148.9E	75	20	98					5	-5				
93092706	19	30.7N	150.9E	75	13	72					0	0				
93092712	20	32.9N	153.1E	75	18						0					
93092718	21	35.6N	155.9E	70	27						0					
			AVERAGE		23	76	151	238	334	661	1	6	10	13	15	17
			# CASES		21	19	17	15	13	9	21	19	17	15	13	9

TYPHOON DOT (24W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93092300	1	18.5N	112.7E	25	30	80	161	247	368	542	0	0	0	-5	-25	-60
93092306	2	18.5N	112.3E	25	41	115	185	294	428	650	5	0	0	-10	-35	-55
93092312	3	18.6N	112.0E	30	12	45	91	177	321	540	0	0	-10	-25	-45	-40
93092318	4	18.7N	111.8E	30	23	45	113	224	338	574	0	0	-15	-35	-50	-25
93092400	5	18.8N	111.6E	30	17	62	148	246	321	516	0	-5	-25	-45	-55	-15
93092406	6	19.0N	111.4E	30	16	77	170	257	344	540	0	-10	-35	-50	-50	-10
93092412	7	19.2N	111.4E	35	8	51	95	117	145	305	0	-15	-35	-45	-30	0
93092418	8	19.4N	111.6E	40	22	79	114	158	212		-5	-25	-40	-45	-15	
93092500	9	19.7N	111.9E	50	41	105	137	190	259		-15	-35	-50	-30	-5	
93092506	10	20.1N	112.2E	60	11	22	43	69	119		5	0	-5	20	25	
93092512	11	20.5N	112.4E	70	6	16	34	54	66		0	-5	10	15	10	
93092518	12	20.8N	112.4E	75	11	18	48	84			0	0	20	20		
93092600	13	21.1N	112.4E	80	12	36	71	108			5	15	30	25		
93092606	14	21.6N	112.5E	75	0	24	48				5	20	20			
93092612	15	22.2N	112.5E	60	5	8	38				0	5	5			
93092618	16	22.8N	112.6E	45	11	18					0	0				
93092700	17	23.4N	112.7E	35	20	24					0	0				
93092706	18	24.0N	112.9E	30	25						0					
			AVERAGE		18	49	100	172	266	524	2	8	20	28	31	29
			# CASES		18	17	15	13	11	7	18	17	15	13	11	7

SUPER TYPHOON ED (25W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93093000	1	12.8N	146.3E	25	6	24	29	18	23	70	0	-5	-15	-20	-25	-25
93093006	2	13.2N	145.7E	30	6	18	45	66	66	63	0	-10	-20	-25	-35	-30
93093012	3	13.5N	145.0E	35	13	23	44	47	26	75	-5	-10	-15	-20	-20	-20

SUPER TYPHOON ED (25W) (CONTINUED)

93093018	4	13.8N	144.4E	40	0	29	37	42	25	110	0	-5	-5	-15	-5	-10
93100100	5	14.0N	143.5E	50	0	18	39	26	34	121	0	-5	-10	-10	-10	-15
93100106	6	14.2N	142.5E	55	13	35	58	70	87	148	0	-10	-20	-15	-15	-25
93100112	7	14.4N	141.7E	65	11	18	67	95	105	136	0	-5	-5	-5	-5	-25
93100118	8	14.6N	141.0E	70	24	51	109	141	130	92	0	-10	-5	-5	-5	-20
93100200	9	14.8N	140.2E	80	16	47	79	84	71	194	0	0	0	-10	-10	-15
93100206	10	15.4N	139.4E	90	18	51	66	68	90	280	0	0	-5	-15	-20	-10
93100212	11	16.0N	138.5E	90	6	5	13	45	99	268	0	-5	-10	-20	-35	-10
93100218	12	16.7N	137.6E	95	6	8	26	65	131	323	-5	-15	-20	-35	-40	-10
93100300	13	17.3N	136.7E	100	5	13	45	98	169	324	-10	-20	-25	-45	-35	-5
93100306	14	17.8N	135.9E	105	5	29	74	131	211	369	-10	-15	-25	-35	-30	-5
93100312	15	18.3N	135.1E	110	5	34	91	163	255	415	-5	-10	-40	-35	-25	-5
93100318	16	18.7N	134.4E	115	11	53	107	180	252	439	-5	-25	-40	-35	-20	-5
93100400	17	19.1N	133.8E	120	8	24	76	171	251	379	0	-30	-35	-25	-15	0
93100406	18	19.5N	133.3E	130	16	69	154	224	260	211	-5	-25	-30	-15	-10	10
93100412	19	19.8N	132.8E	140	5	69	166	222	316	523	-5	5	15	15	5	-5
93100418	20	20.3N	132.7E	140	12	53	102	167	270	428	0	10	20	15	5	5
93100500	21	20.8N	132.7E	135	8	47	101	203	259	338	0	10	20	20	10	0
93100506	22	21.4N	132.9E	130	12	49	106	207	222	255	0	10	15	20	15	0
93100512	23	22.1N	133.2E	120	8	21	94	208	266		0	0	-5	-10	-5	
93100518	24	22.9N	133.5E	110	6	20	95	173	222		0	-5	-10	-5	5	
93100600	25	24.0N	134.0E	105	18	28	111	136	207		0	0	-5	5	5	
93100606	26	24.9N	134.6E	100	12	91	135	222	306		0	0	0	10	0	
93100612	27	25.9N	135.6E	95	20	63	129	209			0	0	10	10		
93100618	28	27.2N	137.0E	90	16	55	121	154			-5	-5	5	0		
93100700	29	28.5N	138.4E	85	24	56	91				0	5	5			
93100706	30	30.0N	139.9E	75	13	42	30				10	15	10			
93100712	31	31.6N	141.7E	65	42	98					0	-5				
93100718	32	33.2N	144.0E	55	56	100					0	-5				
93100800	33	34.5N	146.5E	55	19						-5					
93100806	34	35.7N	149.2E	50	28						-5					
			AVERAGE		14	42	82	130	168	253	2	9	15	18	16	12
			# CASES		34	32	30	28	26	22	34	32	30	28	26	22

TYPHOON FLO (26W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93100112	1	16.7N	128.1E	30	29	69	34	29	45	90	-5	-5	-5	-5	-5	-5
93100118	2	16.8N	127.3E	30	18	5	41	72	98	83	0	0	-5	-10	-15	-5
93100200	3	16.9N	126.3E	35	45	139	211	258	300	380	0	0	-10	-20	-20	0
93100206	4	16.9N	126.0E	35	5	34	58	85	126	233	0	-5	-10	-15	-10	15
93100212	5	16.8N	125.7E	40	8	24	43	69	102	199	-5	-10	-15	-20	-15	10
93100218	6	16.8N	125.4E	45	12	33	37	67	95	129	0	-5	-10	-5	-5	10
93100300	7	16.7N	124.9E	50	25	51	95	147	174	132	-5	-10	-15	-5	5	15
93100306	8	16.7N	124.5E	55	36	69	119	173	157	188	0	0	0	0	5	25
93100312	9	16.6N	124.0E	60	33	59	101	108	56	390	0	-5	0	5	5	25
93100318	10	16.6N	123.4E	65	44	88	127	111	37	495	0	0	5	10	5	25
93100400	11	16.5N	122.7E	70	5	46	54	54	161	625	0	-5	0	15	25	40
93100406	12	16.4N	121.9E	65	11	49	37	116	307	840	0	0	5	15	30	45
93100412	13	16.3N	121.0E	65	5	11	92	220	451	918	-10	-10	0	15	25	40
93100418	14	16.3N	120.2E	60	13	35	140	336	581	1073	-15	0	5	25	30	35
93100500	15	16.2N	119.7E	55	23	97	240	482	724	1301	-5	5	15	25	35	35
93100506	16	16.1N	119.6E	50	52	155	357	601	827	1529	0	5	20	25	40	30
93100512	17	16.2N	119.8E	50	18	72	266	456	687	1519	-5	0	0	0	0	-15
93100518	18	16.4N	120.2E	50	32	167	367	554	826	1732	-5	5	0	5	-5	-15
93100600	19	17.0N	120.9E	45	61	248	432	629	947		0	0	-5	-5	-15	
93100606	20	18.4N	122.1E	40	53	179	293	476	808		0	0	5	0	-5	
93100612	21	19.6N	123.5E	40	107	212	327	560	946		-5	0	0	-5	-10	

SUPER TYPHOON FLO (26W) (CONTINUED)

DTG	WRN NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93100618	22	20.8N	125.0E	40	114	198	358	674	1075		-5	5	-5	-10	-15	
93100700	23	22.0N	126.3E	40	20	34	140	407			-5	-5	-20	-30		
93100706	24	23.3N	127.6E	35	13	84	262	544			0	-10	-25	-30		
93100712	25	25.0N	129.0E	40	30	147	387				-5	-20	-30			
93100718	26	27.1N	130.7E	45	66	213	473				-10	-25	-30			
93100800	27	29.4N	133.3E	50	49	227					-5	-15				
93100806	28	31.7N	136.7E	55	85	271					-10	-15				
93100812	29	34.1N	141.4E	60	44						0					
93100818	30	36.1N	145.4E	60	34						0					
			AVERAGE		37	108	196	302	434	659	3	6	9	13	15	22
			# CASES		30	28	26	24	22	18	30	28	26	24	22	18

TROPICAL STORM GENE (27W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93100618	1	9.1N	142.4E	25	16	30	133	240	336	562	0	5	10	15	20	40
93100700	2	9.4N	141.3E	25	66	113	216	303	402	634	0	5	5	15	20	40
93100706	3	9.9N	140.3E	25	56	165	276	384	492	762	0	0	0	5	20	40
93100712	4	10.8N	139.0E	25	132	147	247	365	521		0	0	5	10	25	
93100718	5	12.0N	137.8E	25	132	149	225	341	504		0	0	0	10	25	
93100800	6	13.3N	136.8E	30	71	98	116	218	310		0	0	0	10	15	
93100806	7	14.4N	136.1E	30	53	107	147	204			0	-5	-5	0		
93100812	8	15.6N	135.2E	30	39	76	97	128			0	-5	0	5		
93100818	9	16.9N	134.3E	35	33	33	65	121			0	5	15	20		
93100900	10	18.1N	133.4E	35	23	47	97				0	0	5			
93100906	11	19.4N	132.9E	35	23	58	97				0	0	10			
93100912	12	20.9N	132.5E	30	36	68					0	5				
93100918	13	22.3N	132.2E	30	39	66					0					
93101000	14	23.7N	132.0E	30	12						0					
93101006	15	25.1N	132.2E	30	11						0					
			AVERAGE		50	90	156	256	428	653	0	2	5	10	21	40
			# CASES		15	13	11	9	6	3	15	13	11	9	6	3

TROPICAL DEPRESSION 28W

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93100706	1	14.2N	119.5E	25	11	73	144	126	130	220	0	5	0	0	5	10
93100712	2	14.9N	120.7E	25	16	80	122	197	314	586	5	0	0	5	10	10
93100718	3	15.5N	121.9E	25	43	133	250	390	516	759	0	0	5	10	10	10
93100800*	4	16.1N	123.1E	25	13	30	114	201			0	0	0	5		
93100812	5	16.5N	124.4E	25	44	154	236	305	350	531	0	0	5	5	5	5
93100818	6	16.5N	124.5E	25	47	96	132	166	197	459	0	5	5	5	5	5
93100900	7	16.5N	124.6E	25	17	35					0	5				
93101206**	8	20.5N	118.1E	25	8	25	58				0	0	5			
93101212	9	20.8N	117.2E	25	21	55	97				0	0	10			
93101218	10	21.1N	116.4E	25	29	49					0	0				
93101300	11	21.4N	115.7E	25	0	28					0	10				
93101306	12	21.8N	115.0E	25	5						0					
93101312	13	22.5N	114.1E	20	12						0					
			AVERAGE		21	69	145	232	302	512	0	2	4	5	7	8
			# CASES		13	11	8	6	5	5	13	11	8	6	5	5

* TD Warning Issued

** Regenerated Warning

TROPICAL STORM HATTIE (29W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93101906*	1	13.2N	163.4E	25	109	137	143	130			5	0	0	-5		
93101918	2	13.7N	160.7E	30	107	102	90	114	184	394	0	0	0	5	5	25
93102000	3	13.9N	159.5E	30	47	86	130	202	312	511	0	0	0	5	5	15
93102006	4	14.3N	158.6E	30	42	77	117	168	268	553	0	-5	0	0	10	10
93102012	5	14.7N	157.8E	30	60	101	151	232	351	665	0	-5	0	0	10	5
93102018	6	15.2N	157.1E	35	68	112	183	287	392	738	0	0	0	10	15	10
93102100	7	15.7N	156.5E	35	93	162	267	383	472	823	0	0	0	5	5	0
93102106	8	16.2N	156.0E	35	104	193	318	423	597	940	0	-5	5	5	0	0
93102112	9	16.8N	155.6E	35	85	187	305	415	641	1058	0	-5	5	0	-5	5
93102118	10	17.5N	155.3E	40	138	252	364	549	747	1273	0	5	10	0	0	15
93102200	11	18.4N	155.0E	40	116	210	294	468	599	1212	0	10	5	0	0	10
93102206	12	19.4N	154.7E	35	45	60	39	89	147		5	10	0	0	5	
93102212	13	20.4N	154.3E	35	18	27	52	84	125		0	-5	-15	-15	-10	
93102218	14	21.3N	153.8E	35	22	20	99	231	256		0	-10	-15	-15	-10	
93102300	15	22.1N	153.4E	40	108	152	253	331	318		-5	-15	-15	-5	-5	
93102306	16	23.9N	154.0E	45	53	128	209	202			-10	-15	-15	-5		
93102312	17	25.0N	154.5E	50	71	59	86	160			-15	-15	-10	-5		
93102318	18	26.0N	155.3E	50	77	58	110				-15	-15	-10			
93102400	19	26.6N	155.9E	50	64	96	249				-15	-10	-10			
93102406	20	27.6N	157.0E	50	49	128					-15	-10				
93102412	21	29.0N	158.4E	45	36	129					-5	-5				
93102418	22	31.0N	160.7E	45	6						0					
93102500	23	33.4N	163.6E	45	7						-10					
			AVERAGE		67	118	183	263	387	817	4	7	6	5	6	10
			# CASES		23	21	19	17	14	10	23	21	19	17	14	10

* TD Warning Issued

TYPHOON IRA (30W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93102718	1	13.2N	143.6E	25	13	12	37	46	55	69	0	0	-5	5	0	-20
93102800	2	13.1N	142.1E	30	21	30	53	64	72	39	-5	-5	-10	0	-10	-30
93102806	3	13.1N	140.6E	30	90	112	132	135	133	66	5	0	5	-5	-20	-40
93102812	4	13.2N	139.1E	35	24	18	24	16	21	110	5	5	15	5	-5	-15
93102818	5	13.4N	137.6E	40	0	26	42	50	69	192	5	15	10	0	-10	-15
93102900	6	13.6N	136.3E	45	18	12	6	35	31	42	0	10	0	-10	-20	-5
93102906	7	13.8N	135.0E	40	45	59	45	48	32	13	5	-10	-20	-35	-45	-20
93102912	8	14.1N	133.7E	45	51	66	62	58	52	8	5	-10	-20	-35	-45	-15
93102918	9	14.4N	132.4E	55	40	26	21	6	26	66	0	-10	-25	-40	-40	5
93103000	10	14.6N	131.1E	65	18	23	43	36	18	58	-5	-15	-25	-30	-20	0
93103006	11	14.8N	129.8E	75	36	47	93	119	125	146	0	-10	-20	-20	-30	5
93103012	12	15.0N	128.5E	85	34	55	90	104	111	138	0	-10	-15	-10	-5	20
93103018	13	15.2N	127.4E	95	33	57	63	75	85	156	0	-10	-5	-5	15	25
93103100	14	15.3N	126.5E	105	5	21	39	76	120	143	0	-5	15	45	30	10
93103106	15	15.4N	125.7E	115	0	16	35	69	109	125	0	5	30	25	5	15
93103112	16	15.6N	124.8E	120	13	35	70	106	129	138	0	15	45	40	30	40
93103118	17	15.7N	124.0E	120	29	75	116	145	157	184	0	5	40	25	10	25
93110100	18	15.9N	123.0E	110	35	75	121	144	139	149	0	25	25	5	15	30
93110106	19	16.1N	122.0E	105	29	46	69	78	74	102	0	15	5	15	20	30
93110112	20	16.3N	121.0E	85	23	45	68	91	102	106	0	20	5	15	20	35
93110118	21	16.5N	120.0E	65	17	30	24	24	23	102	0	0	10	15	25	40
93110200	22	16.8N	119.0E	60	20	31	49	64	71	127	0	5	15	15	15	25
93110206	23	17.1N	118.1E	60	6	8	20	18	50		0	5	0	0	0	
93110212	24	17.4N	117.3E	60	18	29	58	106	172		-5	0	-5	5	5	
93110218	25	17.7N	116.5E	55	33	53	99	140	232		0	-5	0	0	0	
93110300	26	18.1N	115.8E	55	18	37	55	86	101		0	0	10	10	20	

TYPHOON IRA (30W) (CONTINUED)

93110306	27	18.5N	115.0E	55	8	12	18	55			0	0	5	10		
93110312	28	19.0N	114.3E	55	6	12	30	73			0	0	5	10		
93110318	29	19.5N	113.7E	50	0	0	37				0	0	5			
93110400	30	20.0N	113.0E	45	16	53	55				0	0	10			
93110406	31	20.6N	112.3E	45	8	24					0	5				
93110412	32	21.3N	111.6E	40	20	24					0	10				
93110418	33	22.0N	111.2E	35	16						0					
93110500	34	22.4N	111.1E	25	29						0					
			AVERAGE		23	37	56	74	89	104	1	7	14	16	18	21
			# CASES		34	32	30	28	26	22	34	32	30	28	26	22

TROPICAL STORM JEANA (31W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93110500	1	11.0N	154.7E	20	23	29	42	76	81	96	5	5	10	25	35	50
93110506	2	11.3N	153.6E	20	13	24	52	70	81	68	5	5	15	30	40	55
93110512	3	11.6N	152.5E	25	11	37	65	71	79	46	5	10	25	35	40	55
93110518	4	11.9N	151.5E	25	35	55	65	77	86	35	5	10	25	35	40	55
93110600	5	12.1N	150.5E	25	12	18	29	42	70	124	10	25	35	40	45	60
93110606	6	12.3N	149.5E	25	18	32	42	60	91	154	10	20	30	35	40	55
93110612	7	12.6N	148.5E	20	45	69	80	100	150	195	15	15	20	15	15	15
93110618	8	12.9N	147.4E	20	18	40	75	105	143	126	15	20	20	20	20	15
93110700	9	13.2N	146.3E	20	41	81	134	180	220	156	20	20	20	20	25	25
93110706	10	13.4N	145.2E	20	11	34	52	97	130	194	20	20	20	20	20	20
93110712	11	13.6N	144.0E	25	8	5	41	106	126	269	15	15	15	20	20	20
93110718	12	13.8N	142.8E	25	18	43	115	163	162	201	20	20	20	20	20	25
93110800	13	14.1N	141.5E	30	29	71	138	168	212	416	15	10	15	10	10	15
93110806	14	14.6N	140.3E	30	39	87	134	162	244	469	10	10	10	5	5	20
93110812	15	15.3N	139.0E	35	64	124	168	242	342	571	0	0	0	0	0	15
93110818	16	16.2N	137.8E	35	30	93	189	297	415	617	0	0	0	0	5	20
93110900	17	17.1N	136.8E	35	18	71	111	120	154	377	5	5	5	5	5	15
93110906	18	17.9N	136.2E	40	20	117	191	234	252	334	0	0	0	5	10	20
93110912	19	18.5N	135.9E	40	16	71	136	224	317	454	0	0	0	5	5	20
93110918	20	19.1N	135.9E	45	16	39	91	148	203		-5	-5	0	0	0	
93111000	21	19.7N	135.9E	45	8	30	81	155	240		0	0	5	10	20	
93111006	22	20.4N	136.0E	50	11	49	121	198	324		5	15	25	20	20	
93111012	23	20.9N	136.3E	50	18	78	162	293	448		5	15	25	25	25	
93111018	24	21.3N	136.8E	50	12	71	180	323			10	20	30	30		
93111100	25	21.6N	137.3E	50	12	48	139	254			0	5	10	20		
93111106	26	21.8N	137.9E	45	23	83	179				5	5	10			
93111112	27	21.9N	138.4E	45	89	182	288				5	10	15			
93111118	28	21.9N	138.8E	40	66	151					5	10				
93111200	29	21.9N	139.1E	35	17	62					5	5				
93111206	30	21.9N	139.4E	30	70						0					
			AVERAGE		28	66	115	159	199	258	7	10	15	18	20	30
			# CASES		30	29	27	25	23	19	30	29	27	25	23	19

TROPICAL DEPRESSION 32W

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93111800	1	7.7N	129.7E	25	84	119	168				0	0	-5			
93111806	2	7.9N	128.1E	25	55	96					0	0				
93111812	3	8.3N	126.9E	25	30	84					0	0				
93111818	4	8.9N	126.2E	25	29						0					
93111900	5	9.2N	125.6E	25	18						0					
			AVERAGE		44	100	168				0	0	5			
			# CASES		5	3	1				5	3	1			

TROPICAL DEPRESSION 33W

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93111806*	1	14.5N	161.4E	25	18	128	251				0	0	5			
93111818*	2	15.1N	159.6E	25	150	356					0	5				
93111906*	3	15.3N	156.8E	20	6						0					
			AVERAGE		58	243	251				0	3	5			
			# CASES		3	2	1				3	2	1			

* TD Warning Issued

TYPHOON KYLE (34W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93111912	1	10.4N	128.6E	30	29	66	90	93	101	139	0	0	0	0	0	-20
93111918	2	10.7N	127.4E	35	24	74	79	78	54	76	0	5	0	0	0	-25
93112000	3	10.7N	126.4E	35	18	18	47	39	63	142	0	5	0	0	-5	-40
93112006	4	10.8N	125.3E	35	25	39	50	72	108	158	0	0	0	-5	-15	-50
93112012	5	11.0N	124.2E	35	24	58	67	112	152	214	0	-5	0	-10	-20	-40
93112018	6	11.3N	123.0E	40	13	11	46	88	117	202	0	0	0	-10	-20	-20
93112100	7	11.6N	121.8E	40	18	11	58	91	118	201	0	5	-5	-15	-35	15
93112106	8	11.7N	120.7E	40	21	18	52	81	116	226	0	0	-15	-20	-45	15
93112112	9	11.9N	119.6E	40	16	21	59	88	121	303	0	-5	-15	-35	-35	15
93112118	10	12.1N	118.1E	45	29	66	87	121	165		0	-10	-20	-45	-20	
93112200	11	12.2N	116.8E	50	42	72	88	114	175		0	-10	-30	-35	15	
93112206	12	12.4N	115.4E	60	63	80	103	142	205		0	-5	-25	5	25	
93112212	13	12.6N	114.2E	65	29	42	65	123	206		0	-10	-5	30	15	
93112218	14	12.7N	113.0E	70	0	16	47	89			0	-15	-5	10		
93112300	15	12.8N	111.7E	85	6	11	52	155			0	-10	20	5		
93112306	16	12.8N	110.5E	95	8	26	104				-10	0	15			
93112312	17	12.9N	109.3E	85	8	42	117				-10	20	10			
93112318	18	13.0N	107.9E	65	13	49					0	10				
93112400	19	13.3N	106.6E	30	25	89					0	5				
			AVERAGE		22	43	72	100	131	185	1	6	10	15	19	27
			# CASES		19	19	17	15	13	9	19	19	17	15	13	9

TYPHOON LOLA (35W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93120200	1	8.6N	143.3E	30	32	123	210	282	357	398	-5	0	-5	-5	-10	-20
93120206	2	9.3N	141.6E	30	69	122	182	246	288	228	-5	-5	-5	-10	-15	-25
93120212	3	10.1N	139.9E	30	63	103	151	176	194	199	0	-5	-10	-15	-15	-25
93120218	4	10.7N	138.0E	35	51	67	119	156	145	107	-5	-10	-15	-20	-20	-20
93120300	5	11.2N	136.1E	40	18	13	8	5	34	100	0	0	5	10	5	-10
93120306	6	11.6N	134.4E	45	17	13	36	66	103	161	0	0	0	5	0	-5
93120312	7	12.1N	132.6E	50	6	13	40	82	134	200	0	-5	0	0	-5	0
93120318	8	12.8N	130.9E	55	18	29	82	120	153	234	0	0	0	-5	-5	5

TYPHOON LOLA (35W) (CONTINUED)

93120400	9	13.4N	129.5E	60	8	30	59	109	126	231	0	5	5	-5	-10	0
93120406	10	13.8N	128.1E	65	8	42	79	120	147	236	0	0	0	-15	-10	-10
93120412	11	14.1N	126.8E	65	5	60	120	143	192	276	0	-5	0	-10	-5	-10
93120418	12	14.2N	125.7E	70	8	55	118	146	196	254	0	0	-5	-5	0	-20
93120500	13	14.3N	124.7E	75	6	47	54	113	167	209	-5	0	-5	0	-5	-35
93120506	14	14.2N	123.8E	80	0	26	77	106	122	121	0	5	0	5	-10	-50
93120512	15	14.1N	123.0E	80	6	37	94	119	136	138	0	5	5	0	-10	-65
93120518	16	14.0N	122.0E	75	6	42	79	110	130	146	0	5	5	-5	-15	-55
93120600	17	13.8N	120.8E	70	8	45	85	94	72	130	0	5	5	-5	-30	-10
93120606	18	13.3N	119.8E	65	6	13	8	8	61	393	0	10	0	-10	-45	5
93120612	19	12.9N	118.9E	60	0	17	29	42	95	407	-5	-5	-15	-35	-70	0
93120618	20	12.5N	118.0E	55	6	18	26	53	139		-5	-15	-25	-55	-65	
93120700	21	12.1N	117.1E	55	17	24	48	76	153		0	-5	-25	-55	-5	
93120706	22	11.8N	116.2E	60	35	82	135	225	351		-5	-10	-40	-45	10	
93120712	23	11.5N	115.2E	60	23	59	110	222	360		-5	-20	-55	0	20	
93120718	24	11.2N	114.1E	65	41	89	179	329			-10	-35	-45	15		
93120800	25	11.1N	113.0E	75	30	61	145	254			-5	-30	30	25		
93120806	26	11.1N	111.8E	90	8	59	165				0	0	20			
93120812	27	11.3N	110.5E	105	11	81	222				10	45	30			
93120818	28	11.8N	108.9E	95	21	109					0	20				
93120900	29	12.4N	107.2E	50	26	110					0	0				
93120906	30	13.6N	105.6E	35	66						0					
			AVERAGE		21	55	99	136	168	220	2	9	13	14	17	19
			# CASES		30	29	27	25	23	19	30	29	27	25	23	19

TYPHOON MANNY (36W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93120306	1	7.0N	154.2E	25	21	77	142	184	204	244	0	0	10	10	5	10
93120312	2	7.1N	152.2E	25	101	172	243	261	272	274	0	0	5	5	0	15
93120318	3	7.3N	150.2E	30	85	152	194	219	246	222	0	5	5	5	0	15
93120400	4	7.5N	148.1E	30	5	72	102	111	87	221	0	5	5	0	0	15
93120406	5	7.7N	146.0E	30	23	64	87	76	122	290	0	-5	-5	-5	0	10
93120412	6	7.8N	144.0E	35	13	30	66	84	188	344	-5	-10	-10	-5	5	10
93120418	7	8.1N	142.2E	40	16	32	54	128	185	393	-5	-5	-5	0	10	10
93120500	8	8.6N	140.5E	45	12	13	43	115	192	452	0	-5	0	15	25	10
93120506	9	9.3N	138.8E	50	8	51	67	84	79	183	0	0	10	20	20	0
93120512	10	10.0N	137.1E	55	8	38	63	75	129	257	0	5	15	20	20	-5
93120518	11	10.7N	135.2E	60	16	70	105	135	202	315	0	10	20	20	15	-5
93120600	12	11.6N	133.6E	60	37	140	180	307	460	674	0	15	20	15	0	-25
93120606	13	12.7N	133.0E	60	8	23	89	210	376	540	0	5	-5	-10	-25	-50
93120612	14	13.6N	132.1E	55	16	13	62	156	283	466	0	5	0	-15	-30	-75
93120618	15	14.2N	131.0E	55	8	32	111	233	352	486	0	0	-5	-20	-30	-70
93120700	16	14.9N	130.2E	55	24	75	146	248	329	432	0	0	-10	-25	-35	-60
93120706	17	15.4N	129.8E	60	5	37	116	218	359	584	5	-5	-15	-25	-45	-40
93120712	18	15.9N	129.6E	60	12	80	190	361	554	914	0	-10	-25	-35	-75	-45
93120718	19	16.3N	129.7E	65	18	111	253	458	674	1036	-5	-15	-25	-45	-70	-30
93120800	20	16.5N	129.9E	70	8	49	149	233	288	301	-5	-15	-25	-65	-45	20
93120806	21	16.3N	130.1E	75	5	66	171	243	287	310	0	-10	-35	-60	-25	30
93120812	22	15.9N	129.9E	80	8	97	144	196	209	264	5	0	-30	-15	0	35
93120818	23	15.2N	129.4E	80	16	78	122	188	234	311	0	-15	-40	-10	15	40
93120900	24	14.4N	128.6E	85	11	35	65	99	121	185	-5	-40	-30	-15	10	30
93120906	25	13.7N	127.6E	95	0	34	70	82	111	170	-10	-30	-15	-5	20	35
93120912	26	13.3N	126.4E	120	5	18	0	50	117	158	-5	0	10	20	20	35
93120918	27	12.8N	125.2E	115	11	6	8	48	108	125	5	20	25	30	25	35
93121000	28	12.5N	124.0E	105	13	36	34	34	50	85	0	10	25	25	40	45
93121006	29	12.5N	122.8E	85	30	42	37	34	30	74	0	15	30	35	45	40
93121012	30	12.5N	121.8E	80	21	13	60	67	46	37	0	20	25	40	45	35

TYPHOON MANNY (36W) (CONTINUED)

93121018	31	12.3N	120.9E	65	26	74	128	121	109	146	0	15	20	25	30	20
93121100	32	12.0N	120.0E	50	41	106	125	109	128	196	5	15	25	25	30	25
93121106	33	11.5N	119.2E	40	13	51	58	76	106	204	5	10	20	20	20	25
93121112	34	10.9N	118.5E	40	23	30	77	82	80	153	0	10	5	15	10	15
93121118	35	10.6N	117.8E	35	54	104	168	201	224	258	0	0	0	-10	-15	-10
93121200*	36	10.6N	117.0E	30	45	83	117	156			0	0	0	-10		
93121206	37	10.7N	116.3E	30	36	42	36	36	54	267	0	5	5	5	10	10
93121212	38	10.9N	115.6E	30	5	18	21	66	199	354	0	5	0	10	10	-5
93121218	39	10.9N	114.9E	30	6	30	42	138	280	380	0	0	0	10	0	-5
93121300	40	10.8N	114.1E	30	26	32	77	216	335		0	-10	0	0	-10	
93121306	41	10.8N	113.3E	35	18	26	109	247	311		0	-5	5	0	-10	
93121312	42	10.8N	112.5E	40	11	48	165	268			-5	5	0	0		
93121318	43	10.7N	111.6E	40	26	102	233	305			-5	0	-5	-10		
93121400	44	10.2N	110.6E	35	48	178	281				-5	-10	-10			
93121406	45	9.4N	109.3E	35	69	200	253	251			-5	-5	-5	-5		
93121412	46	8.4N	107.8E	35	91	198	225				-5	0	0			
93121418	47	7.6N	106.1E	35	114	178	199				-5	0	0			
93121500	48	7.2N	104.6E	30	43	42	85				0	5	0			
93121506	49	7.1N	103.2E	30	5	75					-5	0				
93121512	50	7.3N	102.0E	25	24	43					0	-5				
			AVERAGE		26	69	117	164	219	324	2	8	12	17	21	26
			# CASES		50	50	48	44	40	38	50	50	48	44	40	38

* TD Warning Issued

TYPHOON NELL (37W)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93122312*	1	7.3N	140.0E	30	0	30	67	100			-5	-10	-15	-20		
93122400*	2	7.7N	137.7E	35	18	47	86	148			-10	-20	-20	-35		
93122412*	3	8.3N	135.3E	45	18	24	63	104			-15	-20	-35	-40		
93122500	4	8.5N	132.7E	50	17	51	86	90	122	126	-15	-20	-20	-10	-15	5
93122506	5	8.5N	131.3E	60	13	24	53	101	134	93	-15	-10	-10	-10	-10	15
93122512	6	8.6N	129.8E	65	13	43	102	181	205	90	-10	-15	-5	-5	-5	15
93122518	7	8.8N	128.3E	65	29	74	145	214	207		-5	-5	0	0	-5	
93122600	8	9.2N	126.8E	70	11	43	102	121	72		-5	-10	-15	-5	10	
93122606	9	9.7N	125.5E	65	21	59	98	101	70		0	-5	-10	0	20	
93122612	10	10.3N	124.3E	65	18	36	25	54	151		0	-5	-5	10	30	
93122618	11	10.9N	123.1E	65	5	13	32	109			0	5	10	25		
93122700	12	11.6N	122.1E	65	34	66	141	248			0	10	20	30		
93122706	13	12.0N	121.1E	60	23	56	131				0	5	20			
93122712	14	12.1N	120.0E	55	34	117	208				0	10	20			
93122718	15	11.9N	119.0E	50	5	36					0	15				
93122800	16	11.5N	118.1E	40	16	50					0	5				
93122806	17	11.0N	117.1E	30	18						0					
			AVERAGE		18	49	96	131	138	104	5	11	15	16	14	12
			# CASES		17	16	14	12	7	3	17	16	14	12	7	3

* TD Warning Issued

6.2.2 NORTH INDIAN OCEAN

This section includes verification statistics for each warning in the North Indian Ocean during 1993.

JTWC FORECAST TRACK AND INTENSITY ERRORS BY WARNING

TROPICAL CYCLONE 01A

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93111218	1	15.3N	64.9E	40	47	71	149	258	395	651	-5	-10	-10	-20	-15	15
93111300	2	16.0N	64.3E	45	31	29	61	165	258	396	-5	-10	-10	-15	0	35
93111306	3	16.8N	63.7E	55	16	59	148	231	305		0	0	-5	0	15	
93111312	4	17.6N	63.3E	60	33	99	196	279	342		0	-5	-10	10	20	
93111318	5	18.4N	63.1E	65	47	123	219	286	360		0	-5	5	20	30	
93111400	6	19.3N	63.2E	70	12	78	144	195	243		0	-5	15	30	40	
93111406	7	20.1N	63.6E	75	33	96	139	174			0	0	25	35		
93111412	8	20.9N	64.2E	80	18	55	114	234			5	30	50	35		
93111418	9	21.6N	64.8E	75	30	72	162				10	30	25			
93111500	10	22.2N	65.4E	65	55	163	356				15	0	-5			
93111506	11	22.6N	66.1E	55	6	78					-5	0				
93111512	12	22.7N	66.8E	45	36	124					0	5				
93111518	13	22.6N	67.5E	35	48						5					
93111600	14	22.3N	67.9E	25	5						5					
			AVERAGE		30	88	169	228	318	524	4	8	16	21	20	25
			# CASES		14	12	10	8	6	2	14	12	10	8	6	2

TROPICAL CYCLONE 02B

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93113012	1	7.6N	91.8E	25	16	17	53	89	118	167	5	5	10	10	5	-25
93113018	2	7.8N	90.9E	30	8	30	59	89	133	185	0	5	5	5	0	-40
93120100	3	8.0N	89.9E	30	77	131	185	227	249	251	0	5	5	0	-5	-35
93120106	4	8.2N	89.1E	30	85	139	189	244	274	221	0	0	0	-5	-25	-40
93120112	5	8.3N	88.2E	30	46	81	124	147	157	65	0	-5	-10	-15	-25	-30
93120118	6	8.5N	87.4E	35	50	66	85	93	81	29	-5	-10	-20	-30	-45	-20
93120200	7	8.7N	86.6E	35	24	42	77	90	69	150	-5	-10	-20	-35	-40	-10
93120206	8	8.8N	85.8E	40	21	55	75	77	38	136	-5	-10	-15	-30	-25	-5
93120212	9	8.9N	85.1E	45	6	29	38	37	96	239	-10	-15	-25	-30	-20	0
93120218	10	9.0N	84.3E	50	25	46	45	69	138	277	-10	-20	-35	-25	-5	0
93120300	11	9.1N	83.4E	55	18	26	51	110	165		0	-5	-10	-5	-5	
93120306	12	9.3N	82.6E	60	0	26	74	115	150		0	-10	-5	-10	0	
93120312	13	9.6N	81.8E	65	18	48	108	151	178		-5	-5	5	0	0	
93120318	14	9.9N	81.1E	75	32	78	140	189	197		-15	0	20	5	0	
93120400	15	10.5N	80.4E	70	37	96	149	195			-5	5	0	0		
93120406	16	11.2N	79.6E	65	13	42	76	138			10	0	0	-5		
93120412	17	11.8N	78.5E	55	11	53	105				15	10	0			
93120418	18	12.4N	77.4E	40	42	77	164				10	10	0			
93120500	19	13.0N	76.3E	30	6	29					0	0				
93120506	20	13.6N	75.2E	25	6	26					0	0				
93120512	21	14.0N	74.1E	25	6						0					
93120518	22	14.2N	73.0E	25	5						0					
			AVERAGE		26	57	100	129	146	173	5	7	10	13	14	21
			# CASES		22	20	18	16	14	10	22	20	18	16	14	10

6.2.3 SOUTHERN HEMISPHERE

This section includes verification statistics for each warning in the South Indian and western South Pacific Ocean from 1 July 1992 to 30 June 1993.

JTWC FORECAST TRACK AND INTENSITY ERRORS BY WARNING

TROPICAL CYCLONE 01S (AVIONA)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
92092712	1	8.5S	88.0E	50	13	46	112	179	224		-15	-20	-15	-10	-5	
92092800	2	9.2S	87.3E	65	18	56	120	178	216		-5	0	10	25	30	
92092812	3	10.2S	86.7E	65	6	29	66	117	149		0	5	20	30	35	
92092900	4	11.5S	86.1E	60	18	36	60	96	110		5	15	20	20	20	
92092912	5	12.7S	85.1E	50	53	60	47	51	60		10	10	10	10	10	
92093000	6	13.7S	84.1E	45	11	25	37	16			10	10	10	10		
92093012	7	14.5S	82.9E	40	16	5	13				0	-5	-5			
92100100	8	14.8S	81.3E	35	23	46					0	0				
			AVERAGE		20	38	65	107	152		6	8	13	18	20	
			# CASES		8	8	7	6	5		8	8	7	6	5	

TROPICAL CYCLONE 02S (BABIE)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
92101818	1	10.2S	81.8E	30	54	126	173	243	287		0	5	5	5	15	
92101906	2	10.8S	81.6E	35	13	26	51	79	96		5	5	10	25	30	
92101918	3	11.4S	81.4E	40	79	153	202	242			5	5	15	30		
92102006	4	12.0S	81.2E	45	56	85	128				5	15	30			
92102018	5	12.6S	80.7E	40	101	145					10	15				
92102106	6	13.1S	79.8E	35	13						0					
			AVERAGE		53	108	139	189	192		4	9	15	20	23	
			# CASES		6	5	4	3	2		6	5	4	3	2	

TROPICAL CYCLONE 03P (JONI)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
92120600	1	9.8S	180.0W	40	21	32	80	142	161		0	-5	0	-5	-25	
92120612	2	10.6S	179.9E	50	5	25	73	90	107		0	-5	-10	-25	-30	
92120700	3	11.7S	179.5E	55	16	54	61	81	112		0	-5	-15	-25	-30	
92120712	4	12.7S	178.5E	65	8	51	79	91	118		0	-20	-25	-25	-30	
92120800	5	13.2S	177.9E	85	13	47	112	206	304		0	5	10	10	0	
92120812	6	13.9S	177.3E	95	17	37	96	183	303		0	0	5	5	5	
92120900	7	14.8S	176.8E	100	11	28	54	92	132		0	-5	-15	-15	-5	
92120912	8	15.8S	176.6E	105	11	12	54	105	162		-10	-15	-15	-5	-5	
92121000	9	16.8S	176.6E	110	11	16	34	61	102		0	5	20	15	5	
92121006	10	17.4S	176.8E	110	8	42	68	113	144		0	10	15	10	0	
92121012	11	17.9S	177.1E	105	11	40	82	152	207		5	20	15	15	5	
92121018	12	18.4S	177.5E	95	18	38	74	101	132		10	20	20	20	15	
92121100	13	18.9S	177.9E	85	5	18	73	139			0	-10	-15	-25		
92121112	14	19.8S	179.0E	75	12	46	113	301			-5	-5	-10	-10		
92121200	15	20.5S	179.4W	65	5	49	199				0	0	0			
92121212*	16	22.4S	177.5W	55	17	126					0	-5				
92121218*	17	26.9S	175.0W	40	68						0					
			AVERAGE		15	41	84	133	166		2	9	13	15	13	
			# CASES		17	16	15	14	12		17	16	15	14	12	

* Warning Issued By NAVPACMETOCCEN

TROPICAL CYCLONE 04S

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
92120718	1	8.6S	49.3E	35	38	59	93	128	163		0	5	10	20	30	
92120800	2	8.6S	48.7E	35	18	26	40	84	135		0	5	10	20	30	
92120806	3	8.6S	48.1E	35	21	40	67	114	168		0	5	10	10	10	
92120812	4	8.5S	47.6E	35	25	30	51	97	163		0	5	10	10	10	
92120818	5	8.5S	47.1E	35	32	66	118	152	241		0	10	10	15	10	
92120900	6	8.5S	46.6E	35	41	78	120	170	296		0	10	5	5	0	
92120906	7	8.5S	46.1E	30	17	45	76	159			5	5	5	5		
92120912	8	8.4S	45.6E	30	53	89	135	240			5	0	0	0		
92120918	9	8.4S	45.2E	30	17	18	94				5	5	0			
92121000	10	8.4S	44.7E	30	33	42	81				0	0	0			
92121006	11	8.2S	44.1E	25	11	64					0	0				
92121012	12	7.8S	43.5E	25	11	99					0	-10				
			AVERAGE		27	55	88	144	195		1	5	6	11	15	
			# CASES		12	12	10	8	6		12	12	10	8	6	

TROPICAL CYCLONE 05S (KEN)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
92121912	1	12.6S	96.0E	35	53	93	146	192	196		0	0	10	20	25	
92122000	2	13.6S	94.5E	45	29	55	47	66	142		0	5	5	10	20	
92122012	3	15.0S	93.4E	40	29	64	107	168	270		0	-5	-5	-10	-5	
92122100	4	16.0S	91.9E	40	34	63	115	189	240		0	0	0	10	25	
92122112	5	16.1S	90.4E	40	21	98	200	272	314		0	0	0	5	5	
92122200	6	15.5S	88.8E	40	18	92	169	230			0	5	10	0		
92122212	7	14.4S	86.6E	35	24	55	70				0	5	0			
92122300	8	13.7S	84.2E	25	21	21					0	5				
92122312	9	13.5S	81.8E	25	6						0					
			AVERAGE		26	68	123	186	233		0	3	4	9	16	
			# CASES		9	8	7	6	5		9	8	7	6	5	

TROPICAL CYCLONE 06P (NINA)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
92122318	1	11.9S	139.8E	35	11	45	88	125	160		0	0	-5	-10	10	
92122406	2	12.5S	140.5E	40	18	65	110	147	195		5	0	-5	15	25	
92122418	3	13.5S	141.0E	50	18	23	32	72	124		5	-5	5	10	10	
92122500	4	14.0S	141.2E	55	17	48	106	162	247		15	20	20	10	5	
92122506	5	14.2S	141.5E	60	13	60	118	174	264		5	20	25	15	0	
92122518	6	14.4S	142.0E	45	13	24	18	46	88		20	15	5	-15	-20	
92122606	7	14.4S	142.6E	35	5	29	69	108	120		10	10	0	-10	-20	
92122618	8	14.2S	143.1E	30	11	62	112	128	154		15	5	-5	-20	-30	
92122706	9	13.7S	143.9E	35	0	24	13	24	75		0	0	0	0	0	
92122718	10	13.2S	145.0E	40	11	42	96	163	209		-5	-15	-20	-15	-5	
92122806	11	13.4S	146.2E	50	5	13	46	64	5		0	0	5	5	-5	
92122818	12	13.8S	147.7E	60	16	55	79	36	48		0	0	5	0	0	
92122906	13	14.4S	149.7E	65	29	48	23	75	112		-10	-15	-25	-25	-30	
92122918	14	15.1S	151.3E	65	8	100	175	260	338		0	-10	-15	-25	-35	
92123006	15	14.5S	152.6E	70	5	26	53	108	167		5	10	10	0	-10	
92123018	16	13.8S	153.7E	65	5	32	77	119	180		0	0	-5	-5	-10	
92123106	17	13.1S	155.2E	65	24	74	126	198	316		0	-5	-10	-20	-25	
92123118	18	12.3S	156.9E	70	18	47	103	201	322		-5	-5	-15	-15	-15	
93010106	19	11.7S	159.2E	70	35	104	228	382	597		-5	-10	-15	-10	-5	
93010118	20	11.5S	162.2E	75	18	58	142	260	424		0	-5	0	5	15	
93010206	21	11.4S	166.1E	75	35	106	240	399	504		0	-5	0	5	10	
93010218	22	11.4S	170.6E	70	13	75	181	253			0	5	0	-5		

TROPICAL CYCLONE 06P (NINA) (CONTINUED)

DTG	WRN NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93010300	23	11.6S	173.3E	65	5	29	75	254			0	5	5	0		
93010306	24	11.9S	176.0E	60	34	105	222	448			0	0	0	5		
93010312	25	12.3S	179.0E	55	17	12	62				0	5	10			
93010318	26	13.1S	178.0W	50	8	41	102				5	10	10			
93010406*	27	16.5S	173.2W	40	29	100					0	10				
93010418*	28	21.3S	169.3W	25	185						-5					
			AVERAGE		22	54	104	175	221		4	7	8	10	14	
			# CASES		28	27	26	24	21		28	27	26	24	21	

* Warning Issued By NAVPACMETOCCEN

TROPICAL CYCLONE 07P (KINA)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
92122618	1	10.0S	170.0E	35	13	5	18	33	53		0	5	5	-5	-10	
92122706	2	11.1S	170.5E	40	13	32	79	135	201		5	5	-5	-10	-10	
92122718	3	12.1S	170.8E	50	13	18	24	50	90		5	-5	-15	-20	-10	
92122806	4	12.9S	171.4E	70	29	58	88	112	157		-10	-20	-30	-25	-5	
92122818	5	13.5S	172.0E	90	24	55	121	212	303		10	0	0	10	20	
92122906	6	14.1S	172.6E	110	5	45	95	146	188		0	5	15	25	30	
92122918	7	14.5S	172.7E	120	8	31	63	100	127		0	5	15	20	15	
92123006	8	14.8S	172.5E	115	18	55	96	175	269		10	15	25	25	20	
92123018	9	15.0S	172.4E	105	8	11	29	86	153		10	15	20	25	20	
92123106	10	15.2S	172.6E	95	6	26	68	130	192		5	5	5	5	-10	
92123118	11	15.6S	173.1E	90	18	48	115	176	226		0	-5	-5	-25	-40	
93010106	12	15.9S	174.2E	85	8	55	90	91	90		0	5	-10	-25	-20	
93010112	13	16.0S	174.9E	85	0	18	16	18	30		0	-5	-25	-25	-25	
93010118	14	16.1S	175.6E	80	8	31	70	120	177		0	-10	-25	-20	-15	
93010200	15	16.3S	176.4E	85	21	50	91	161	211		-5	-20	-20	-15	-5	
93010206	16	16.6S	177.3E	90	18	36	62	124	185		-5	-20	-15	-5	0	
93010212	17	17.1S	178.2E	100	8	41	79	98	129		0	5	5	10	5	
93010218	18	17.7S	179.2E	100	17	28	62	175	327		-5	-5	-5	-5	0	
93010300	19	18.5S	179.7W	95	8	46	76	102	264		0	0	5	0	10	
93010306	20	19.3S	178.4W	90	11	44	132	291			0	10	10	5		
93010318	21	21.7S	175.7W	75	16	17	104				5	10	10			
93010406*	22	24.3S	173.0W	60	57	37					5	5				
93010418*	23	28.1S	170.6W	50	152						5					
			AVERAGE		21	36	75	127	177		4	8	13	15	14	
			# CASES		23	22	21	20	19		23	22	21	20	19	

* Warning Issued By NAVPACMETOCCEN

TROPICAL CYCLONE 08P

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93010200*	1	18.5S	161.0W	30	49	194	353				0	-10	10			
93010212*	2	19.9S	156.7W	45	45	55					5	10				
93010300*	3	21.1S	152.1W	35	39						0					
			AVERAGE		45	125	353				2	10	10			
			# CASES		3	2	1				3	2	1			

* Warning Issued By NAVPACMETOCCEN

TROPICAL CYCLONE 09P

DTG	WRN NO.	BEST TRACK LAT	LONG	WIND	POSITION ERRORS 00	12	24	36	48	72	WIND ERRORS 00	12	24	36	48	72
93011118*	1	12.0S	149.3W	30	6	111	179	216	393		0	5	15	30	40	
93011206*	2	11.4S	152.1W	30	26	106	373	671			0	5	15	30		
93011218*	3	12.6S	154.3W	30	88	348	669				10	20	25			
93011306*	4	15.6S	153.6W	25	29	62					5	5				
93011318*	5	18.7S	151.9W	25	30						0					
			AVERAGE		36	157	407	444	394		3	9	18	30	40	
			# CASES		5	4	3	2	1		5	4	3	2	1	

* Warning Issued By NAVPACMETOCCEN

TROPICAL CYCLONE 10S (COLINA)

DTG	WRN NO.	BEST TRACK LAT	LONG	WIND	POSITION ERRORS 00	12	24	36	48	72	WIND ERRORS 00	12	24	36	48	72
93011418	1	10.7S	67.4E	35	21	41	91	118	141		0	-5	-5	5	20	
93011506	2	11.3S	66.0E	45	8	42	42	46	83		0	-5	0	10	20	
93011518	3	11.6S	64.3E	55	44	118	168	178	179		-5	0	10	20	20	
93011606	4	12.1S	63.1E	55	55	84	134	183	211		0	5	5	-5	-5	
93011618	5	12.8S	61.9E	50	25	51	40	85	168		0	0	0	0	-10	
93011706	6	13.7S	60.3E	50	13	34	25	90	150		0	-5	0	-10	-25	
93011718	7	14.0S	58.5E	55	6	42	117	174	237		0	5	0	-20	-25	
93011806	8	15.2S	57.4E	55	13	79	127	199	320		0	-5	-20	-30	-20	
93011818	9	17.2S	56.5E	65	24	49	99	183	299		-5	-15	-20	-15	0	
93011906	10	19.0S	55.5E	85	12	13	60	192	311		0	-5	5	20	25	
93011918	11	21.1S	54.9E	95	24	108	236	356			10	20	35	30		
93012006	12	24.2S	55.1E	90	28	141	277				0	10	5			
93012018	13	27.5S	57.3E	75	6	24					0	-5				
93012106	14	30.3S	61.2E	65	11						0					
			AVERAGE		21	64	118	164	211		1	7	9	15	17	
			# CASES		14	13	12	11	10		14	13	12	11	10	

TROPICAL CYCLONE 11S (DESSILIA)

DTG	WRN NO.	BEST TRACK LAT	LONG	WIND	POSITION ERRORS 00	12	24	36	48	72	WIND ERRORS 00	12	24	36	48	72
93012012	1	20.7S	43.1E	35	48	172					0	10				
93012100	2	21.7S	45.5E	25	6						5					
			AVERAGE		27	173					3	10				
			# CASES		2	1					2	1				

TROPICAL CYCLONE 12S (EDWINA)

DTG	WRN NO.	BEST TRACK LAT	LONG	WIND	POSITION ERRORS 00	12	24	36	48	72	WIND ERRORS 00	12	24	36	48	72
93012018	1	12.1S	84.7E	35	48	88	142	217	296		0	-10	-10	-10	-10	
93012106	2	12.7S	83.5E	45	21	37	70	118	188		0	0	5	0	0	
93012118	3	13.1S	82.0E	50	29	70	123	188	241		0	5	0	0	-15	
93012206	4	13.3S	80.1E	50	0	18	34	58	78		5	0	0	-20	-40	
93012218	5	13.5S	77.8E	55	13	36	55	67	82		0	0	-20	-40	-35	
93012306	6	13.7S	75.4E	60	35	58	84	91	110		-5	-20	-45	-45	-35	
93012318	7	14.0S	73.0E	80	26	42	79	105	109		0	-10	0	10	15	
93012406	8	14.5S	70.6E	105	29	29	41	77	96		-5	-10	10	20	20	
93012418	9	15.0S	68.4E	110	40	57	75	79	43		-10	35	40	30	20	
93012506	10	15.5S	66.2E	100	13	42	79	111	136		10	10	15	10	0	
93012518	11	16.0S	64.1E	95	21	20	67	84	83		5	5	0	-15	-20	
93012606	12	16.9S	62.5E	90	37	56	62	58	57		5	0	-10	-15	-20	
93012618	13	18.2S	61.0E	90	16	34	35	40	91		0	0	0	-5	-15	
93012706	14	19.9S	60.0E	100	45	71	74	42	113		0	0	-5	-5	0	

TROPICAL CYCLONE 12S (EDWINA) (CONTINUED)

93012718	15	22.0S	59.6E	100	18	54	145	222	235		0	-5	-5	0	10	
93012806	16	24.6S	59.3E	95	48	103	174	220			-5	-10	-5	10		
93012818	17	28.0S	59.4E	90	31	85	177				-5	5	20			
93012906	18	31.7S	59.0E	75	13	43					0	10				
93012918	19	35.3S	58.8E	50	60						15					
			AVERAGE		29	53	90	112	131		4	8	11	15	17	
			# CASES		19	18	17	16	15		19	18	17	16	15	

TROPICAL CYCLONE 13S (LENA)

	WRN	BEST TRACK				POSITION ERRORS						WIND ERRORS				
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93012412	1	14.8S	119.5E	35	52	42	13	0	66		0	-5	-5	0	10	
93012500	2	15.3S	118.9E	45	39	58	53	8	61		0	5	10	25	40	
93012512	3	15.9S	118.9E	50	13	28	70	120	150		5	0	15	25	35	
93012600	4	16.2S	118.1E	55	32	18	81	131	199		0	10	20	30	40	
93012612	5	15.9S	117.1E	50	29	84	161	247	351		-5	-5	0	10	30	
93012700	6	15.4S	116.1E	50	42	83	147	219	226		0	0	10	30	40	
93012712	7	15.5S	114.5E	50	16	36	94	63	48		0	5	20	35	45	
93012800	8	15.7S	112.7E	50	29	52	23	67	176		0	15	25	35	45	
93012812	9	15.9S	110.5E	40	40	32	77	155			0	0	-5	-10		
93012900	10	15.9S	109.4E	35	0	67	151	235			0	0	-5	-10		
93012912	11	15.8S	108.8E	35	13	59					-5	-10				
			AVERAGE		28	51	87	125	160		1	5	12	21	36	
			# CASES		11	11	10	10	8		11	11	10	10	8	

TROPICAL CYCLONE 14P

	WRN	BEST TRACK				POSITION ERRORS						WIND ERRORS				
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93012606	1	13.4S	137.0E	30	38	133	213	294	408		0	0	10	30	40	
93012618	2	14.2S	135.7E	35	13	39	84	146	224		0	0	5	5	10	
93012706	3	14.5S	134.4E	35	41	88	148	208	263		0	10	5	10	10	
93012718	4	15.0S	133.2E	25	6	8					0	-5				
93012806	5	15.5S	131.8E	25	21	77					0	0				
93020600**	6	22.7S	112.7E	35	6	8	75	175	257		0	0	10	20	30	
93020612	7	22.4S	111.1E	35	6	53	144	239	234		0	5	15	20	20	
93020700	8	21.6S	108.6E	30	8	57					0	5				
			AVERAGE		18	58	133	213	278		0	3	9	17	22	
			# CASES		8	8	5	5	5		8	8	5	5	5	

** Regenerated Warning

TROPICAL CYCLONE 15P (LIN)

	WRN	BEST TRACK				POSITION ERRORS						WIND ERRORS				
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93013100*	1	12.6S	173.8W	35	58	26	24	136	444		10	10	-5	-20	-40	
93013112*	2	13.8S	172.0W	50	31	91	117	143	132		-10	-20	-20	-25	-20	
93020100*	3	15.5S	170.5W	65	18	29	21	36	133		-20	-15	-25	-20	10	
93020112*	4	17.4S	169.5W	75	24	136	299	452	681		-10	-25	-20	10	15	
93020200*	5	19.2S	168.2W	90	48	138	234	347	510		-5	5	35	45	55	
93020212*	6	20.6S	166.7W	85	86	142	233	366			5	30	40	40		
93020300*	7	21.5S	165.3W	55	23	93	204				0	0	0			
93020312*	8	22.5S	165.0W	40	40	121					5	5				
93020400*	9	23.2S	165.3W	30	13						0					
			AVERAGE		38	98	162	247	380		7	14	21	27	28	
			# CASES		9	8	7	6	5		9	8	7	6	5	

* Warning Issued By NAVPACMETOCCEN

TROPICAL CYCLONE 16P (OLIVER)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93020418	1	14.9S	150.0E	35	21	42	54	109	158		0	-5	-15	-25	-25	
93020506	2	14.6S	150.0E	45	34	68	139	219	252		0	-5	-25	-30	-35	
93020518	3	15.2S	150.6E	60	13	42	75	77	75		5	-5	0	0	-10	
93020606	4	15.6S	151.4E	80	5	30	45	71	84		-5	-10	-10	-25	-30	
93020618	5	16.1S	152.1E	90	26	83	149	166	151		-5	-15	-35	-35	-30	
93020706	6	16.8S	152.2E	100	11	37	55	78	111		-10	-25	-30	-20	-20	
93020718	7	17.4S	151.9E	115	11	18	58	130	229		-5	-5	0	5	10	
93020806	8	18.0S	151.9E	115	8	18	56	107	167		-5	5	5	15	25	
93020818	9	18.6S	152.0E	100	8	36	73	109	127		0	0	10	25	30	
93020906	10	19.4S	152.6E	95	0	26	64	88	105		0	10	20	25	30	
93020918	11	19.8S	153.4E	80	16	8	13	28	45		0	5	10	15	15	
93021006	12	20.0S	154.2E	65	21	49	94	151	241		0	0	10	10	5	
93021018	13	20.5S	154.8E	55	6	23	53	103	189		0	10	10	5	10	
93021106	14	21.1S	155.2E	40	17	46	106				-5	-5	-10			
93021118	15	21.8S	155.5E	35	17	37	94	203			0	0	0	0		
93021206	16	22.7S	155.4E	35	16	77	207				5	5	10			
93021218	17	22.9S	154.4E	30	47	152					5	5				
			AVERAGE		17	47	84	118	149		3	7	13	17	21	
			# CASES		17	17	16	14	13		17	17	16	14	13	

TROPICAL CYCLONE 17P (MICK)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93020518*	1	17.1S	172.6W	30	65	96	112	150	184		10	10	15	-5	-5	
93020606*	2	18.3S	173.7W	35	30	69	100	111	128		-5	-5	-15	-20	-20	
93020618*	3	18.7S	175.5W	35	18	62	150	194	252		0	5	5	0	0	
93020706*	4	19.2S	177.2W	45	56	74	195	372	491		0	15	10	10	5	
93020718*	5	20.5S	178.5W	45	74	112	120	764			-10	0	5	0		
93020806*	6	22.3S	179.6W	45	64	87	125				-10	5	5			
93020818*	7	24.0S	179.4E	40	30	52					-10	-10				
93020906*	8	25.4S	178.6E	35	55						-5					
			AVERAGE		49	79	134	319	264		6	7	9	7	8	
			# CASES		8	7	6	5	4		8	7	6	5	4	

* Warning Issued By NAVPACMETOCCEN

TROPICAL CYCLONE 18P (NISHA)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93021200*	1	12.8S	165.2W	25	67	133	130	96	49		5	5	-5	-5	-5	
93021212*	2	15.4S	164.2W	30	41	181	299	457	582		0	-10	-15	-25	-30	
93021300*	3	17.6S	163.4W	45	24	101	182	219	195		10	10	-10	-25	-30	
93021312*	4	19.1S	162.1W	50	18	94	194	308	402		0	-5	-15	-20	-20	
93021400*	5	20.2S	159.9W	60	45	107	196	269	295		-20	-30	-30	-25	-20	
93021412*	6	21.7S	156.9W	65	53	96	135	137	171		0	-5	-10	-10	0	
93021500*	7	23.5S	153.4W	60	17	24	85	297			-5	-5	-5	5		
93021512*	8	25.8S	149.8W	50	16	129	365				0	-5	5			
93021600*	9	28.5S	146.6W	45	24	240					0	10				
93021612*	10	32.1S	145.3W	30	67						5					
			AVERAGE		38	123	199	255	283		5	9	12	16	18	
			# CASES		10	9	8	7	6		10	9	8	7	6	

* Warning Issued By NAVPACMETOCCEN

TROPICAL CYCLONE 19S (FINELLA)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93021306	1	22.7S	51.1E	40	37	76	185	304	351		0	-5	-5	5	10	
93021318	2	24.5S	52.6E	60	37	72	114	126	89		-15	-20	-5	0	-10	
93021406	3	26.2S	54.8E	75	6	28	132	161	155		-5	5	10	5	0	
93021418	4	27.9S	56.9E	75	13	80	97	98			0	5	5	10		
93021506	5	29.8S	57.5E	65	26	110	154				5	5	10			
93021518	6	31.1S	58.7E	55	6	31					0	5				
			AVERAGE		21	67	137	173	199		4	8	7	5	7	
			# CASES		6	6	5	4	3		6	6	5	4	3	

TROPICAL CYCLONE 20P (OLI)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93021612	1	17.5S	176.7E	40	39	58	90	142			-5	-5	5	30		
93021700	2	19.4S	178.0E	50	5	11	64				0	5	5			
93021712	3	21.7S	179.6E	50	11	52					0	5				
93021800	4	24.1S	178.4W	40	8						0					
			AVERAGE		16	41	78	143			1	5	5	30		
			# CASES		4	3	2	1			4	3	2	1		

TROPICAL CYCLONE 21P (POLLY)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93022500	1	15.8S	157.9E	35	8	29	49	74	105		0	0	-5	-5	0	
93022512	2	16.8S	158.2E	45	18	16	29	61	109		-5	-10	-5	5	0	
93022518	3	17.2S	158.4E	55	11	57	104	159	217		0	10	20	20	10	
93022600	4	17.5S	158.6E	60	8	12	26	88	161		5	5	15	15	5	
93022612	5	18.0S	159.1E	70	12	29	62	85	64		0	5	5	-5	-15	
93022700	6	18.2S	159.6E	75	34	54	66	53	53		-10	-20	-30	-40	-35	
93022712	7	18.3S	160.1E	85	11	11	39	41	65		0	-5	-10	-10	-15	
93022800	8	18.6S	160.3E	95	6	54	88	123	269		-5	-10	-10	-15	-20	
93022812	9	19.5S	159.9E	100	16	78	215	376	482		0	5	20	15	5	
93030100	10	20.8S	160.3E	95	24	126	310	485	578		5	10	15	15	25	
93030112	11	22.3S	162.2E	90	8	37	92	132			0	-5	-10	-5		
93030200	12	24.6S	165.6E	85	30	69	86				0	-5	0			
93030212	13	27.3S	169.7E	75	13	161					0	10				
93030300	14	30.2S	173.4E	55	11						0					
			AVERAGE		15	57	98	153	211		2	8	12	14	13	
			# CASES		14	13	12	11	10		14	13	12	11	10	

TROPICAL CYCLONE 22P (ROGER)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93031200	1	10.3S	157.2E	25	24	62	147	214	263		5	5	5	10	20	
93031212	2	11.6S	156.3E	30	54	106	173	237	310		0	0	5	15	20	
93031300	3	13.3S	156.2E	40	41	91	166	227	222		0	5	15	25	20	
93031312	4	14.7S	155.9E	45	51	42	45	68	97		0	5	10	15	20	
93031400	5	15.9S	155.6E	45	34	41	33	86	116		0	0	5	15	25	
93031412	6	17.1S	155.5E	50	8	43	121	148	154		-5	-10	0	10	15	
93031500	7	18.7S	155.6E	55	43	111	131	139	150		-5	-5	5	10	15	
93031512	8	20.7S	156.0E	55	34	118	186	254			-10	-5	-10	-20		
93031600	9	22.1S	155.8E	50	57	105	154	265			-10	-15	-20	-15		
93031612	10	23.1S	155.7E	50	20	45	94	229	435		-10	-15	-10	-5	-5	
93031700	11	24.2S	155.7E	50	23	94	206	326			-5	-5	-5	-5		

TROPICAL CYCLONE 22P (ROGER) (CONTINUED)

93031712	12	24.2S	156.2E	45	22	95	163				-5	-5	-5			
93031800	13	23.4S	157.0E	40	20	70					-5	-5				
			AVERAGE		34	79	135	200	219		5	6	8	13	18	
			# CASES		13	13	12	11	8		13	13	12	11	8	

TROPICAL CYCLONE 23P (PREMA)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93032712	1	14.3S	171.5E	40	11	5	26	62	100		0	-10	-40	-60	-65	
93032800	2	14.9S	171.0E	60	13	6	50	75	81		0	-25	-45	-50	-55	
93032812	3	15.4S	170.3E	95	11	50	75	95	81		-15	-20	-20	-25	-35	
93032900	4	15.9S	169.2E	120	28	29	54	91	186		-10	-5	-5	-15	-15	
93032906	5	16.4S	168.7E	125	23	13	37	116	260		-5	-5	-15	-10	-5	
93032912	6	17.0S	168.2E	125	8	8	38	150	307		-5	-5	-10	-10	0	
93032918	7	17.7S	167.8E	125	8	8	95	226	370		-5	-5	-5	0	10	
93033000	8	18.5S	167.5E	125	8	39	172	346	487		-5	-5	0	15	20	
93033006	9	19.3S	167.4E	125	0	101	277	469	618		-10	-10	0	15	25	
93033012	10	20.3S	167.9E	125	8	78	219	352	453		-15	-10	10	20	20	
93033018	11	21.1S	168.8E	120	20	111	229	313			-10	0	15	25		
93033100	12	22.0S	170.0E	115	30	104	187	271			-5	15	25	35		
93033112	13	24.0S	173.6E	90	18	80	210				10	10	10			
93040100	14	25.7S	177.8E	70	24	30					0	0				
			AVERAGE		15	48	129	214	295		7	9	15	23	25	
			# CASES		14	14	13	12	10		14	14	13	12	10	

TROPICAL CYCLONE 24S (JOURDANNE)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93040306	1	14.4S	84.6E	35	17	68	151	222	290		0	10	10	0	-15	
93040318	2	14.4S	83.0E	35	5	51	79	106	157		0	0	-10	-25	-35	
93040406	3	15.1S	81.3E	45	13	21	13	67	125		0	-10	-25	-35	-45	
93040418	4	16.0S	79.6E	65	8	18	45	92	190		0	-5	-20	-35	-45	
93040506	5	16.7S	77.8E	90	21	43	82	164	269		0	-10	-15	-20	-15	
93040518	6	17.6S	76.4E	110	20	24	75	158	241		-5	-10	-10	-10	-5	
93040606	7	18.6S	75.4E	125	11	75	162	254	363		-5	-5	0	5	5	
93040618	8	19.2S	75.2E	120	11	58	105	168	241		-5	0	10	10	10	
93040706	9	19.6S	75.4E	110	36	90	150	227	318		0	10	10	20	20	
93040718	10	19.8S	75.6E	95	0	8	30	66	97		0	0	5	0	0	
93040806	11	20.0S	75.8E	85	12	34	55	61			5	15	15	20		
93040818	12	20.2S	75.8E	65	49	66	87				0	0	10			
93040906	13	20.6S	76.1E	55	8	16					5	20				
93040918	14	21.3S	76.5E	35	0						0					
			AVERAGE		16	44	87	145	230		2	7	12	16	20	
			# CASES		14	13	12	11	10		14	13	12	11	10	

TROPICAL CYCLONE 25S (MONTY)

	WRN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	WIND	00	12	24	36	48	72	00	12	24	36	48	72
93041018	1	16.1S	105.5E	40	12	74	172	240	267		0	0	15	35	35	
93041106	2	17.5S	106.2E	50	37	106	158	166	173		0	10	30	30	25	
93041118	3	18.8S	107.5E	45	5	48	112				0	5	5			
93041206	4	19.3S	108.3E	30	18	71					0	0				
			AVERAGE		18	75	148	204	220		0	4	17	33	30	
			# CASES		4	4	3	2	2		4	4	3	2	2	

TROPICAL CYCLONE 26S (KONITA)

DTG	WRN NO.	BEST TRACK LAT	LONG	WIND	POSITION ERRORS 00	12	24	36	48	72	WIND ERRORS 00	12	24	36	48	72
93050212	1	7.4S	71.4E	45	26	36	45	64	60		-5	-5	-10	-30	-45	
93050218	2	7.7S	71.0E	50	29	36	54	90	125		-5	0	-5	-20	-35	
93050300	3	7.9S	70.6E	50	72	91	126	163	202		5	5	0	-10	-25	
93050306	4	8.2S	70.1E	55	72	103	145	180	218		0	0	-5	-10	-30	
93050312	5	8.5S	69.6E	55	51	88	144	214	310		0	-5	-10	-10	0	
93050400	6	9.2S	68.6E	65	70	118	186	276	365		-10	-15	-20	-10	15	
93050412	7	10.0S	68.2E	75	8	42	79	159	260		0	0	5	15	30	
93050500	8	10.7S	68.3E	85	8	34	96	187	276		-10	0	20	40	40	
93050512	9	11.2S	68.4E	85	16	74	160	227	257		0	15	35	35	25	
93050600	10	11.2S	68.6E	70	64	145	218	250			10	30	35	35		
93050612	11	10.7S	68.9E	45	11	8	8				10	15	15			
93050700	12	10.4S	68.7E	35	8	26					5	5				
93050712	13	10.7S	68.3E	30	5						0					
			AVERAGE		34	67	115	182	231		5	8	15	22	27	
			# CASES		13	12	11	10	9		13	12	11	10	9	

NOTE: Intensity peaked at 93050506 at 90kt between warning times

TROPICAL CYCLONE 27P (ADEL)

DTG	WRN NO.	BEST TRACK LAT	LONG	WIND	POSITION ERRORS 00	12	24	36	48	72	WIND ERRORS 00	12	24	36	48	72
93051306	1	6.2S	155.5E	30	48	129	223	270	277		0	-5	0	15	35	
93051318	2	7.8S	154.0E	40	45	104	146	154	200		-5	0	15	35	35	
93051406	3	8.9S	151.8E	45	11	23	73	71	103		0	5	5	15	25	
93051418	4	9.6S	149.9E	40	11	70	65	119			0	5	10	20		
93051506	5	10.3S	148.7E	35	17	43	206				0	10	20			
93051518	6	10.5S	146.7E	30	59	217					5	10				
93051606	7	9.0S	143.8E	25	43						5					
			AVERAGE		34	98	143	154	194		2	6	10	21	32	
			# CASES		7	6	5	4	3		7	6	5	4	3	

7. TROPICAL CYCLONE SUPPORT SUMMARY

7.1 TROPICAL CYCLONE FORECASTER'S REFERENCE GUIDE

C.R. Sampson, J.-H. Chu
and
R.A.Jeffries
Naval Research Laboratory, Marine
Meteorology Division, Monterey, CA

Development of a Tropical Cyclone Forecaster's Reference Guide continues. The guide consists of seven chapters. They are: 1) Tropical Cyclone Warning Support, 2) Tropical Climatology, 3) Tropical Cyclone Formation, 4) Tropical Cyclone Motion, 5) Forecast Aids, 6) Tropical Cyclone Intensity, and (7)Tropical Cyclone Structure. The first three chapters have been published as Technical Notes (available from Naval Research Laboratory (NRL)). The other four chapters are in preparation. The chapter-by-chapter publishing format not only makes the edition and inclusion of updated information easy, but also provides tropical meteorology training notes for aerographers. After all of the chapters are complete, they will be transferred to an interactive video disk format, saving considerable storage space which is especially important for shipboard use.

7.2 AUTOMATED TROPICAL CYCLONE FORECASTING SYSTEM (ATCF) UPGRADE

T.L. Tsui, A.J. Scrader, R.A. Jeffries
and
C.R. Sampson
Naval Research Laboratory, Marine
Meteorology Division, Monterey, CA

The ATCF has been used operationally at JTWC since 1988. The current system runs on an IBM-DOS operating system. NRL, Monterey is adapting the ATCF to the UNIX operating system under the program direction of the Space Warfare and Systems Command. The new ATCF will use industry standard X-Window/Motif for window management and will communicate with the Tactical Environmental Support System (TESS) 3.0. The first phase of the project is expected to be completed in the summer of 1995.

7.3 PROTOTYPE AUTOMATED TROPICAL CYCLONE HANDBOOK (PATCH)

C.R. Sampson and R.A. Jeffries
Naval Research Laboratory
Marine Meteorology Division, Monterey, CA

PATCH is an expert system designed to provide tropical cyclone forecast and training guidance for the western North Pacific Ocean to JTWC. The scope of the project has expanded to include expertise pertaining to tropical cyclone formation, motion, intensification and dissipation, and structure and structure change. The expert system is an integral part of the ATCF upgrade. Initially PATCH will be in a basic stand-alone mode. Ultimately, it will be interactive with the ATCF.

7.4 TCM-93 MINI-FIELD EXPERIMENT

P. A. Harr and R. L. Elsberry
Naval Postgraduate School, Monterey, CA

The Naval Postgraduate School (NPS) and the Office of Naval Research (ONR) Marine Meteorology Program co-sponsored a mini-field experiment near Guam during July-August 1993. The Experiment Operations Center was collocated with JTWC, which provided space, shared its meteorological data bases and facili-

tated the TCM-93 operations. JTWC TDOs participated in routine meteorological discussions.

The objectives and organization of the experiment were almost the same as a similar experiment during 1992, as described in the TCM-92 Operations Plan (Elsberry et al., 1992, NPS Technical Report). Each objective involves understanding of the role of long-lived tropical Mesoscale Convective Systems (MCS) on the motion and formation of tropical cyclones.

During the period, 21 July 1993 to 12 August 1993, USAF Reserve WC-130 aircraft and crews of the 815th Tactical Airlift Squadron, Kessler Air Force Base, Mississippi, deployed to the western North Pacific. Operating from Guam, crews flew seven missions of 7-11 hours duration into tropical cyclones and nearby MCSs to collect flight-level and dropwindsonde observations in support of the TCM-93 mini-field experiment as summarized in the NPS Technical Report (Harr et al., 1993). Some special observations were collected with the new Andersen Air Force Base WSR-88D Doppler radar. Three of the seven WC-130 missions were MCS-tropical cyclone interaction cases, and four were MCS structure, merger, or tropical cyclone genesis cases. Analyses of these data sets are in progress.

7.5 TROPICAL SYNOPTIC ANALYSIS MODERNIZATION AND IMPROVEMENT PROJECT

L. E. Carr III, R. A. Jeffries
and
R. L. Elsberry
Naval Postgraduate School, Monterey, CA

An effort to improve the quality of tropical synoptic analyses and the process by which they are produced has been initiated. A pilot real-time analysis effort associated with this project was conducted in July/August 1993 in support of the ONR- and NPS-sponsored mini-field experiment TCM-93. The ultimate goal of this project is to equip the tropical analyst to produce highly efficient and interactive (man/machine) analyses of the tropical atmosphere. The two essential components to be developed as a part of this project are:

- a comprehensive knowledge base of tropical synoptic conceptual models based heavily on satellite imagery interpretation to facilitate interpretation of available conventional data; and

- sophisticated workstation-based imagery and data manipulation tools tailored to the specific needs of the tropical analyst.

Although manual analyses of tropical circulations permit subjective incorporation of satellite imagery cloud patterns, present objective analysis techniques can utilize only satellite cloud-drift winds and soundings. If an objective analysis lacks structure clearly discernible from cloud patterns, a human analyst must presently redraw all the objectively produced contours or streamlines. The key premise of this analysis modernization and improvement program is that the most efficient way to let the human mind contribute to the meteorological analysis process is by contributing to the quality control of the conventional data and, most importantly, by generating additional "synthetic" data via satellite imagery interpretation. Subsequent objective analyses of the modified conventional data augmented with the synthetic data must then necessarily, but implicitly, incorporate the input of the human analyst, without requiring time-intensive drawing of every analysis line. If desired, the analyst may further refine the analysis by adjusting some of the objectively produced analysis lines.

The synoptic analyses supporting TCM-93 are documented in some detail in the Appendix to Harr et al., 1993. A number of ideas and techniques related to the analysis modernization project were introduced or tested, such as: (i) increased temporal compositing over that used by JTWC; (ii) confirming and refining imagery interpretation techniques and conceptual mod-

els; and (iii) deriving synthetic data from the center position of moving TUTT cells.

7.6 MONSOONAL INTERACTIONS LEADING TO SUDDEN TROPICAL CYCLONE TRACK CHANGES

L. E. Carr III and R. L. Elsberry
Naval Postgraduate School, Monterey, CA

Nearly every year, one or more tropical cyclones are observed to undergo a particularly severe type of track change accompanied by an enhancement or surge in the monsoon southwesterly winds in the vicinity of the tropical cyclone. This type of track change typically consists of a rapid slowing of westward movement to either quasi-stationary or tight cyclonic looping motion, followed by a strong acceleration on a substantially more northward heading. The sharp northward turn routinely approaches or exceeds 90 degrees and is rarely well-forecast by objective guidance. Recent examples include Typhoons Abe (1990), Caitlin (1991), Ted (1992), and Robyn (1993).

Through the sponsorship of ONR, an extensive study of the monsoon surge track change phenomenon has been initiated. The first stage of the research has focused on revealing the basic dynamical processes involved by integrating a barotropic model with various idealized initial conditions, and comparing the model fields and vortex tracks with NOGAPS 500 hPa analyses and JTWC official best tracks of actual monsoon surge track change cases. The results achieved thus far establish that to a first order, the track change can be characterized as a binary interaction and coalescence of: (i) a large, dispersive vortex representing a monsoon cyclone or depression; and (ii) dispersion-resistant vortex representing a tropical cyclone that is embedded in the eastern portion of the monsoon cyclone. During the coalescence, the beta-effect causes part of the monsoon cyclone energy to be radiated away, forming an elongated anticyclone approximately 1200 km to the southeast. The enhanced monsoon surge winds are associates with a confluent, high gradient region that develops between the monsoon cyclone and the anticyclone. It is the strong monsoon surge, which produces a significant southerly steering flow across the tropical cyclone center, that causes the storm to track on a more northward track after coalescence with the monsoon cyclone occurs.

A manuscript documenting the above results has been submitted to Monthly Weather Review for publication and should appear sometime in late 1994. Research on the nature of monsoon surge track changes is ongoing and will include the role of diabatic heating, and prospects for improving the forecastability of the phenomenon.

7.7 HYBRID FORECAST AIDS

D.B. Mundell
Joint Typhoon Warning Center, Guam

Beginning in 1991, steps were undertaken to develop a set of hybrid forecast aids that would reduce the chances for very large forecast errors in difficult forecast situations. The objective was to combine the historically best-performing forecast aids together into a single aid that would have lower overall errors than any of its components. JTWC forecasters wanted to see if a consensus approach to tropical cyclone forecasts would significantly improve the quality of its warnings.

In the first version of this effort , two hybrids named BLND "blended" and WGTD "weighted" were created based on the long-term performance of nine standard forecast aids downloaded from FLENUMETOCCEN. These aids required the TDO to manually enter each of the component aids into a computer to derive the hybrid output. Subsequent analysis of these hybrids revealed that BLND and WGTD did, in fact, have the lowest overall errors of any of

JTWC's forecast aids, but that 1) too much of an emphasis was being placed on climatological aids relative to the dynamic forecast aids; 2) the need to manually enter data was too time-consuming; 3) they lacked a suitable error-checking routine; and 4) a simple average of the best-performing guidance yielded nearly the same performance as more complicated, statistically-based weighting functions.

Since 1992, the following modifications have been made to the original set of hybrid forecast aids to rectify the deficiencies described in the preceding paragraph:

1) Four climatological aids have been deleted from the BLND and two from the WGTD hybrids, and a new hybrid based exclusively on dynamic forecast aids called DAVE, or "dynamic average" has been created.

2) The hybrid calculations have been automated as a batch file which runs on the ATCF terminals and inserts the hybrid forecasts in the aids file after performing an error-checking routine.

3) The hybrids have been simplified; for the western North Pacific basin, BLND is the smple average of JTWC's six primary forecast aids - OTCM, CSUM, FBAM, JT92, CLIP and HPAC; WGTD is a weighted average of FLENUMETOCCEN forecast guidance - OTCM (29%), CSUM (22%), FBAM (14%), JT92 (14%), HPAC (14%), CLIP (7%); and DAVE is a simple average of all of the dynamic forecast aids and extrapolated forecasts from numerical models - NOGAPS (NGPS), Bracknell (EGRR), Japanese Typhoon Model(JTYM), JT92, FBAM, OTCM and CSUM.

4) BLND and WGTD hybrid forecast algorithms have also been developed for the North Indian Ocean and the Southern Hemisphere based on the historical performance of FLENUMETOCCEN forecast aids in each of these tropical cyclone regions.

The performance of each hybrid, and a head-to-head comparison with each of its component parts and with the official JTWC forecast against the final best tracks for the western North Pacific for 1993 are listed in Table 7-1.

Table 7-1 COMPARISON OF BLND, WGTD, AND DAVE GUIDENCE WITH THEIR COMPONENT PARTS AND WITH THE OFFICIAL JTWC FORECAST FOR THE WESTERN NORTH PACIFIC FOR 1993. Negative values indicate that the hybrid performed better than indicated component forecast aid.

	BLND	JTWC	OTCM	CSUM	FBAM	JT92	CLIP	HPAC	
24hr	119nm	(+8)	-14	-10	-20	-9	-17		
48hr	216nm	(+3)	-28	-20	-14	-8	-30	-38	
72hr	308nm	-15	-52	-36	-40	-29	-56	-56	
	WGTD	**JTWC**	**OTCM**	**CSUM**	**FBAM**	**JT92**	**CLIP**	**HPAC**	
24hr	116nm	(+5)	-16	-13	-5	-3	-12	-19	
48hr	215nm	(+2)	-28	-21	-14	-9	-31	-39	
72hr	308nm	-15	-52	-35	-40	-29	-55	-56	
	DAVE	**JTWC**	**OTCM**	**CSUM**	**FBAM**	**JT92**	**NGPS**	**EGRR**	**JTYM**
24hr	110nm	(+2)	-23	-19	-12	-9	-54	-40	-1
48hr	195nm	-19	-47	-41	-34	-29	-70	-34	-6
72hr	298nm	-26	-61	-47	-51	-43	-29	-16	na

BIBLIOGRAPHY

Atkinson, G. D. and C. R. Holliday, 1977: Tropical cyclone minimum sea-level pressure and maximum sustained wind relationship for the western North Pacific. *Monthly Weather Review*, **105**, No. 4, pp 421-427 (also Fleet Weather Central/JTWC Technical Note 75-1).

Boothe, M.A., P.A. Harr and R.L. Elsberry, 1993: Interaction between a mesoscale convective system and the large-scale monsoon flow during TCM-92. Preprints, 20th Conf. on Hurr. and Trop. Meteor., (Paper 15A.3).

Brand, S., 1970: Interaction of binary tropical cyclones of the western North Pacific Ocean. *Journal of Applied Meteorology*, **9**, pp 433-441.

Brand, S., 1972: Very Large and Very Small Typhoons of the Western North Pacific Ocean. *J. Meteor. Soc. Japan*, **50,** pp 332-341.

Bureau of Meteorology (Northern Territory Region), 1993: Darwin Tropical Diagnostic Statement(s), Jan through Dec. The Regional Director, Bureau of Meteorology, GPO Box 735, Darwin, Northern Territory 0801, Australia.

Carr, L.E. III and R.L. Elsberry, 1994: Monsoon interactions leading to sudden tropical cyclone track changes. Submitted to the *Monthly Weather Review*.

Climate Analysis Center, 1993: Climate Diagonostics Bulletin. Dept of Commerce, Washington, D.C. month by bulletins.

Dean, G.A., 1954: An example of tropical cyclogenesis symmetrical with respect to the equator. Oahu Research Center (Institute of Geophysics) — University of California Report No. 3, 6 pp. plus figs. and append. [Available on request from the Dept. of Meteorology, University of Hawaii, 2525 Correa Rd., Honolulu, HI 96822.]

Diercks, J. M., R. C. Weir and M. K. Kopper, 1982: Forecast Verification and Reconnaissance Data for Southern Hemisphere Tropical Cyclones (July 1980 through June 1982). NOCC/JTWC Technical Note 82-1, 77 pp.

Dong, K. and C. J. Neumann, 1983: On the relative motion of binary tropical cyclones. *Monthly Weather Review*, **111**, pp 945-953.

Dunnavan, G. M., 1981: Forecasting Intense Tropical Cyclones Using 700 mb Equivalent Potential Temperature and Central Sea-Level Pressure. NOCC/JTWC Technical Note 81-1, 12 pp.

Dunnavan, G. M., E. J. McKinley, P. A. Harr, E. A. Ritchie, M. A. Boothe, M. A. Lander and R. L. Elsberry, 1992: Tropical Cyclone Motion (TCM-92) mini-field experiment summary. Tech. Report NPS-MR-93-001, Naval Postgraduate School, Monterey, CA 93943.

Dunnavan, G.M., R.L. Elsberry, P.A. Harr, E.J. McKinley and M.A. Boothe, 1993: Overview of the 1992 Tropical Cyclone Motion (TCM-92) mini-field experiment. Preprints, 20th Conf. on Hurr. and Trop. Meteor., (Paper 15A.1).

Dvorak, V. F., 1975: TC Intensity Analysis and Forecasting from Satellite Imagery. *Monthly Weather Review*, **103**, No. 5, pp 420-430.

Dvorak, V. F., 1984: Tropical Cyclone Intensity Analysis Using Satellite Data. NOAA Technical Report NESDIS 11, 46 pp.

Elsberry, R.L., G.M. Dunnavan and E.J. McKinley, 1992: Operations plan for the tropical cyclone motion (TCM-92) mini-field experiment. Tech. Report NPS-MR-92-002, Naval Postgraduate School, Monterey, CA 93943, 46 pp.

Glass, M., and G.W. Felde, 1990: Tropical storm structure analysis using SSM/I and OLS data. 5th Intl. Conf. on Interactive and Info. Processing Systems for Meteor., Oceanogr. and Hydrol., Anaheim, CA, Amer. Meteor. Soc., 432-437.

Guard, C.P., 1983: A Study of Western North Pacific Tropical Storms and Typhoons that Intensify after Recurvature. First Weather Wing Technical Note-83/002, 28 pp.

Herbert, P. H. and K. O. Poteat, 1975: A Satellite Classification Technique for Subtropical Cyclones. NOAA Technical Memorandum NWS SR-83, 25 pp.

Holland, G. J., 1980: An analytical model of wind and pressure profiles in hurricanes. *Monthly Weather Review*, **108**, No. 8, pp 1212-1218.

Holland, G.J. and M.A. Lander, 1993: The meandering nature of tropical cyclone tracks. *Journal of the Atmospheric Sciences*, 50, No 9, pp 1254-1266).

Holliday, C. R. and A. H. Thompson, 1979: Climatological characteristics of rapidly intensifying typhoons. *Monthly Weather Review*, **107**, No 8, pp 1022-1034.

Japan Meteorlogical Agency, 1976: Manual for Typhoons. (English Version), Japan Meteorological Agency, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo, 277 pp.

Jarvinen, B.R. and C.J. Neumann, 1979: Statistical forecast of tropical cyclone intensity. NOAA Technical Memorandum NWS NHC-10, 22 pp.

Jarrell, J.D., S. Brand and D.S. Nicklin, 1978: An analysis of Western Pacific Tropical Cyclone Forecast Errors. *Monthly Weather Review*, **106**, pp. 925-937.

JTWC, 1991: Tropical Cyclones Affecting Guam (1671-1990). NOCC/JTWC Technical Note 91-2, 45 pp.

Keen, R.A. 1982: The role of cross-equatorial tropical cyclone pairs in the Southern Oscillation. *Monthly Weather Review*, **110**, pp 1405-1416.

———, 1988: Equatorial westerlies and the Southern Oscillation. *Proceedings of the U.S. TOGA workshop on western Pacific air-sea interaction, U.S. TOGA Report No. 8*, UCAR, Boulder, CO, 207pp. [Copy avaliable on request from the Dept. of Meteorology, University of Hawaii, 2525 Correa Rd., Honolulu, HI 96822.]

Harr, P.A., R.L. Elsberry, E.A. Ritche, H.E. Willoughby, M.A. Boothe, L.E. Carr III, and R.A. Jeffries, 1993: Tropical Cyclone Motion (TCM-93) Field Experiment Summary. Tech Report NPS-MR-93-004, Naval Postgraduate School, Montery, CA 93943, 120 pp.

Lander, M. A., 1990: Evolution of the cloud pattern during the formation of tropical cyclone twins symmetrical with respect to the equator. *Monthly Weather Review*, **118**, No. 5, pp 1194-1202.

Lander, M.A., 1993: A case study of the low-level summer monsoon circulation of the western North Pacific as a large-scale cyclonic gyre. Preprint Volume of the 20th Conference on Hurricanes and Tropical Meteorology. May 10-14, 1993, San Antonio, TX, pp 463-466.

Lander, M.A., 1994: An exploring analysis of the relationships between tropical storm formation in the Western North Pacific and ENSO, *Monthly Weather Review*, **122**, No. 4, pp 636-651.

Lander, M. A. and G. J. Holland, 1993: On the interaction of tropical-cyclone scale vortices: I. Observations. *Quarterly Journal of the Royal Meteorological Society*, **50**, No 9, pp 1254-1266.

Luther, D.S., D.E. Harrison and R.A. Knox, 1983: Zonal winds in the Central Equtorial Pacific and El Nino. *Science*, **222**, pp 327-330.

Matsumoto, C. R., 1984: A statistical method for one- to three-day tropical cyclone track prediction. Colorado State University Department of Atmospheric Science, Paper 379, 201 pp.

McKinley, E. J., 1992: An analysis of mesoscale convective systems observed during the 1992 Tropical Cyclone Motion field experiment. M.S. Thesis, Naval Postgraduate School, Monterey, CA 93943, 101 pp.

McKinley, E.J., and R.L. Elsberry, 1993: Observations during TCM-92 of the role of tropical mesoscale convective systems in tropical cyclogenesis. Preprints, 20th Conf. on Hurr. and Trop. Meteor., (Paper 13A.3).

Mevill, R.T., 1982: The comparison of large and small tropical cyclones. Colorado State University Department of Atmospheric Science, Paper 352, 75 pp.

Mundell, D.B., 1990: Prediction of Tropical Cyclone Rapid Intensification Events. Thesis for fulfillment of Master's degree submitted to Colorado State University, 186 pp.

OFCM, 1993: National Hurricane Operations Plan, U.S. Dept. of Commerce, Washington, D.C., p E-1.

Ramage, C.S., 1986: El Nino. *Scientific American*, May Issue, pp 77-84

Ramage,C.S.,andA.M.Hori,1981: Meteorological aspects of El Nino. *Monthly Weather Review*, **109**, pp 1827-1835.

Rasmusson, E.M. and T.H. Carpenter, 1982: Variations in tropical sea surface temperature and surface wind fields associated with the Southern Oscillation/El Nino. *Monthly Weather Review*, **115**, pp 354-384.

Ritchie, E.A., 1993: Contributions by mesoscale convective systems to the formation of tropical cyclones. Preprints, 20th Conf. on Hurr. and Trop. Meteor., (Paper13A.5).

Sadler, J. C. 1979: Tropical Cyclone Initiation by the Upper-Tropospheric Trough. Naval Environmental Prediction Research Facility Technical Paper No. 2-76, 103 pp.

Sadler, J.C., M.A. Lander, A.M. Hori, and L.K. Oda, 1987: Tropical marine climatic Atlas, Vol II, Pacific Ocean. UHMET 87-02, University of Hawaii, Department of Meteorology, 14 pp.

Sandgathe, S. A., 1987: Opportunities for tropical cyclone motion research in the Northwest Pacific region. Technical Report NPS 63-87-006, Naval Postgraduate School, Monterey, CA 93943, 36 pp.

Shoemaker, D.N., 1991: Characteristics of Tropical Cyclones Affecting the Philippine Islands. NOCC/JTWC Technical Note 91-01, 35 pp.

Weatherford, C.L. and W.M. Gray, 1985: Typhoon Structural Variability. Colorado State University Department of Atmospheric Science, Paper No. 391, 77 pp.

Weir, R. C., 1982: Predicting the Acceleration of Northward-moving Tropical Cyclones using Upper-Tropospheric Winds. NOCC/JTWC Technical Note 82-2, 40 pp.

Williams, F.R., G.H. Jung and R.E. Englebretson; 1993: Forecasting Handbook for the Philippine Islands and Surrounding Waters. NRL/PU/7541--92-0001, Naval Rresearch Lab, Monterey, CA, 358 pp.

Wirfel, W. P. and S. A. Sandgathe, 1986: Forecast Verification and Reconnaissance Data for Southern Hemisphere Tropical Cyclones (July 1982 through June 1984). NOCC/JTWC Technical Note 86-1, 102 pp.

Xu, Y. and C. J. Neumann, 1985: A Statistical Model for the Prediction of Western North Pacific Tropical Cyclone Motion. NOAA Technical Memorandum NWS NHC 28, 30 pp.

APPENDIX A
DEFINITIONS

BEST TRACK - A subjectively smoothed path, versus a precise and very erratic fix-to-fix path, used to represent tropical cyclone movement, and based on an assessment of all available data.

CENTER - The vertical axis or core of a tropical cyclone. Usually determined by cloud vorticity patterns, wind and/or pressure distribution.

EPHEMERIS - Position of a body (satellite) in space as a function of time; used for gridding satellite imagery. Since ephemeris gridding is based solely on the predicted position of the satellite, it is susceptible to errors from vehicle wobble, orbital eccentricity, the oblateness of the Earth, and variation in vehicle speed.

EXPLOSIVE DEEPENING - A decrease in the minimum sea-level pressure of a tropical cyclone of 2.5 mb/hr for at least 12 hours or 5 mb/hr for at least six hours (Dunnavan, 1981).

EXTRATROPICAL - A term used in warnings and tropical summaries to indicate that a cyclone has lost its "tropical" characteristics. The term implies both poleward displacement from the tropics and the conversion of the cyclone's primary energy source from the release of latent heat of condensation to baroclinic processes. It is important to note that cyclones can become extratropical and still maintain winds of typhoon or storm force.

EYE - The central area of a tropical cyclone when it is more than half surrounded by wall cloud.

FUJIWHARA EFFECT - A binary interaction where tropical cyclones within about 750 nm (1390 km) of each other begin to rotate about a common midpoint (Brand, 1970; Dong and Neumann, 1983).

INTENSITY - The maximum sustained 1-minute mean surface wind speed, typically within one degree of the center of a tropical cyclone.

MAXIMUM SUSTAINED WIND - The highest surface wind speed averaged over a 1-minute period of time. (Peak gusts over water average 20 to 25 percent higher than sustained winds.)

MONSOON DEPRESSION - A tropical cyclonic vortex characterized by: 1) its large size, the outer-most closed isobar may have a diameter on the order of 600 nm (1000 km); 2) a loosely organized cluster of deep convective elements; 3) a low-level wind distribution which features a 100-nm (200-km) diameter light-wind core which may be partially surrounded by a band of gales; and, 4) a lack of a distinct cloud system center. Note: most monsoon depressions which form in the western North Pacific eventually acquire persistent central convection and accelerated core winds marking its transition into a conventional tropical cyclone.

MONSOON GYRE - A mode of the summer monsoon circulation of the western North Pacific characterized by: 1) a very large nearly circular low-level cyclonic vortex that has an outer-most closed isobar with diameter on the order of 1200 nm (2500 km); 2) a cloud band rimming the southern through eastern periphery of the vortex/surface low; 3) a relatively long (two week) life span - initially, a subsident regime exists in its core and western and northwestern quadrants with light winds and scattered low cumulus clouds; later, the area within

the outer closed isobar may fill with deep convective cloud and become a monsoon depression or tropical cyclone; and, 4) the large vortex cannot be the result of the expanding wind field of a preexisting monsoon depression or tropical cyclone. Note: a series of small or very small tropical cyclones may emerge from the "head" or leading edge of the peripheral cloud band of a monsoon gyre (Lander, 1993).

RAPID DEEPENING - A decrease in the minimum sea-level pressure of a tropical cyclone of 1.75 mb/hr or 42 mb for 24-hours (Holliday and Thompson, 1979).

RECURVATURE - The turning of a tropical cyclone from an initial path toward the west and poleward to east and poleward, after moving poleward of the mid-tropospheric subtropical ridge axis.

SIGNIFICANT TROPICAL CYCLONE - A tropical cyclone becomes "significant" with the issuance of the first numbered warning by the responsible warning agency.

SIZE - The areal extent of a tropical cyclone, usually measured radially outward from the center to the outer-most closed isobar. Based on an average radius of the outer-most closed isobar, size categories in degrees of latitude follow: 1° to 2° = very small, 3° = small, 4° to 5° = medium (average), 6° to 9° = large, and 10° or greater = very large (Brand, 1972 and a modification of Merrill, 1982).

STRENGTH - The average wind speed of the surrounding low-level wind flow, usually measured within one to three degrees of the center of a tropical cyclone (Weatherford and Gray, 1985).

SUBTROPICAL CYCLONE - A low pressure system that forms over the ocean in the subtropics and has some characteristics of a tropical circulation, but not a central dense overcast. Although of upper cold low or low-level baroclinic origins, the system can transition to a tropical cyclone.

SUPER TYPHOON - A typhoon with maximum sustained 1-minute mean surface winds of 130 kt (67 m/sec) or greater.

TROPICAL CYCLONE - A non-frontal, migratory low-pressure system, usually of synoptic scale, originating over tropical or subtropical waters and having a definite organized circulation.

TROPICAL DEPRESSION - A tropical cyclone with maximum sustained 1-minute mean surface winds of 33 kt (17 m/sec) or less.

TROPICAL DISTURBANCE - A discrete system of apparently organized convection, generally 100 to 300 nm (185 to 555 km) in diameter, originating in the tropics or subtropics, having a non-frontal, migratory character and having maintained its identity for 12- to 24-hours. The system may or may not be associated with a detectable perturbation of the low-level wind or pressure field. It is the basic generic designation which, in successive stages of development, may be classified as a tropical depression, tropical storm, typhoon or super typhoon.

TROPICAL STORM - A tropical cyclone with maximum 1-minute mean sustained surface winds in the range of 34 to 63 kt (17 to 32 m/sec), inclusive.

TROPICAL UPPER-TROPOSPHERIC TROUGH (TUTT) - A dominant climatological system and a daily upper-level synoptic feature of the summer season, over the tropical North Atlantic, North Pacific and South Pacific Oceans (Sadler, 1979).

TYPHOON (HURRICANE) - A tropical cyclone with maximum sustained 1-minute mean surface winds of 64 to 129 kt (33 to 66 m/sec). West of 180° E longitude they are called typhoons and east of 180° E longitude hurricanes.

WALL CLOUD - An organized band of deep cumuliform clouds that immediately surrounds the central area of a tropical cyclone. The wall cloud may entirely enclose or partially surround the center.

WESTERLY WIND BURST - A short-duration low-level westerly wind event along and near the equator in the western Pacific Ocean (and sometimes in the Indian Ocean) (Luther et al. 1983). Typically, a westerly wind burst (WWB) lasts a few days and has westerly winds of at least 10 kt (5 m/sec) (Keen 1988). Most WWBs occur during the monsoon transition months of April-May, and November-December. They show some relationship to the ENSO phenomenon (Luther et al. 1983; Ramage 1986). Some WWBs are even more energetic, with wind speeds of 30 kt (15 m/sec) observed during well-developed systems. These intense WWBs are associated with a large cluster of deep-convective cloud along the equator. An intense WWB is a necessary precursor to the formation of tropical cyclone twins symmetrical with respect to the equator (Keen 1982; Lander 1990).

APPENDIX B

NAMES FOR TROPICAL CYCLONES IN THE WESTERN NORTH PACIFIC OCEAN AND SOUTH CHINA SEA

Column 1		Column 2		Column 3		Column 4	
ANGELA	AN-gel-ah	**ABE**	ABE	**AMY**	A-mee	**AXEL**	AX-ell
BRIAN	BRY-an	**BECKY**	BECK-ee	**BRENDAN**	BREN-dan	**BOBBIE**	BOB-ee
COLLEEN	COL-leen	**CECIL**	CEE-cil	**CAITLIN**	KATE-lin	**CHUCK**	CHUCK
DAN	DAN	**DOT**	DOT	**DOUG**	DUG	**DEANNA**	dee-AN-na
ELSIE	ELL-see	**ED**	ED	**ELLIE**	ELL-ee	**ELI**	EE-lye
FORREST	FOR-rest	**FLO**	FLO	**FRED**	FRED	**FAYE**	FAY
GAY	GAY	**GENE**	GEEN	**GLADYS**	GLAD-iss	**GARY**	GAR-ee
HUNT	HUNT	**HATTIE**	HAT-ee	**HARRY**	HAR-ee	**HELEN**	HELL-en
IRMA	IR-ma	**IRA**	EYE-ra	**IVY**	EYE-vee	**IRVING**	ER-ving
JACK	JACK	**JEANA**	JEAN-ah	**JOEL**	JOLE	**JANIS**	JAN-iss
KORYN	ko-RIN	**KYLE**	KYE-ell	**KINNA**	KIN-na	**KENT**	KENT
LEWIS	LOU-iss	**LOLA**	LOW-lah	**LUKE**	LUKE	**LOIS**	LOW-iss
MARIAN	MAH-rian	**MANNY***	MAN-ee	**MELISSA***	meh-LISS-ah	**MARK**	MARK
NATHAN	NAY-than	**NELL**	NELL	**NAT**	NAT	**NINA**	NEE-nah
OFELIA	oh-FEEL-ya	**OWEN**	OH-en	**ORCHID**	OR-kid	**OSCAR***	OS-car
PERCY	PURR-see	**PAGE**	PAGE	**PAT**	PAT	**POLLY**	PA-lee
ROBYN	ROB-in	**RUSS**	RUSS	**RUTH**	RUTH	**RYAN**	RYE-an
STEVE	STEEV	**SHARON**	SHAR-on	**SETH**	SETH	**SIBYL**	SIB-ill
TASHA	TA-sha	**TIM**	TIM	**TERESA***	teh-REE-sah	**TED**	TED
VERNON	VER-non	**VANESSA**	vah-NES-ah	**VERNE**	VERN	**VAL**	VAL
WINONA	wi-NO-nah	**WALT**	WALT	**WILDA**	WILL-dah	**WARD**	WARD
YANCY	YAN-see	**YUNYA**	YUNE-yah	**YURI**	YOUR-ee	**YVETTE**	ee-VET
ZOLA	ZO-lah	**ZEKE**	ZEEK	**ZELDA**	ZELL-dah	**ZACK**	ZACK

* Name changes: MANNY replaced MIKE in 1991; MELISSA replaced MIREILLE, TERESA replaced THELMA in 1992, and OSCAR replaced OMAR in 1993.

NOTE 1: Names are assigned in rotation and alphabetically. When the last name in Column 4 (ZACK) has been used, the sequence will begin again with the first name in Column 1 (ANGELA).

NOTE 2: Pronunciation guide for names are italicized.

SOURCE: CINCPACINST 3140.1V

APPENDIX C
CONTRACTIONS

A-track	Along-track
AB	Air Base
ABW	Air Base Wing
ABIO	Significant Tropical Weather Advisory for the Indian Ocean
ABPW	Significant Tropical Weather Advisory for the Western Pacific Ocean
ACCS	Air Control Center Squadron
ACFT	Aircraft
ADP	Automated Data Processing
AFB	Air Force Base
AFGWC	Air Force Global Weather Central
AFTN	Airfield Fixed Telecommunications Network
AIREP	Aircraft (Weather) Report
AJTWC	Alternate Joint Typhoon Warning Center
AMOS	Automatic Meteorological Observing Station
AOR	Area of Responsibility
APT	Automatic Picture Transmission
ARC	Automated Remote Collection (system)
ARGOS	(International Service for Drifting Buoys)
ATCF	Automated Tropical Cyclone Forecast (system)
AUTODIN	Automated Digital Network
AWDS	Automated Weather Distribution System
AWN	Automated Weather Network
BLND	Blended (Hybrid Aid)
CCWF	Combined Confidence Weighted Forecast
CDO	Central Dense Overcast
CEC	Circular Exhaust Cloud
CI	Current Intensity
CIV	Civilian
CLD	Cloud
CLIM	Climatology
CLIP or CLIPER	Climatology and Persistence Technique
CM	Centimeter(s)
C-MAN	Coastal-Marine Automated Network
COMNAVMETOCCOM	Commander Naval Meteorology and Oceanography Command
COARE	Coupled Ocean-Atmosphere Response Experiment
CPA	Closest Point of Approach
CPHC	Central Pacific Hurricane Center
CSC	Cloud System Center
CSUM	Colorado State University Model
DAVE	Name of a Hybrid Aid
DDN	Defense Data Network
DEG	Degree(s)
DET	Detachment
DFS	Digital Facsimile System
DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense
DSN	Defense Switched Network
DTG	Date Time Group
EGGR	Bracknell Model
FBAM	FNOC Beta and Advection Model
FI	Forecast Intensity (Dvorak)
FLENUMETOCCEN	Fleet Numerical Meteorology and Oceanography Center
FT	Foot/Feet
GMS	Geostationary Meteorological Satellite
GMT	Greenwich Mean Time

GOES	Geostationary Operational Environmental Satellite
GTS	Global Telecommun-ications System
hPa	Hectopascal
HPAC	Mean of XTRP and CLIM Techniques (Half Persistence and Climatology)
HF	High Frequency
HR	Hour(s)
HRPT	High Resolution Picture Transmission
ICAO	International Civil Aviation Organization
INIT	Initial
INST	Instruction
IR	Infrared
JTWC	Joint Typhoon Warning Center
JTWC92 or JT92	Statistical-Dynamical Objective Technique
JTYM	Japanese Typhoon Model
KM	Kilometer(s)
KT	Knot(s)
LAN	Local Area Network
LAT	Latitude
LLCC	Low-Level Circulation Center
LONG	Longitude
LUT	Local User Terminal
LVL	Level
M	Meter(s)
MAX	Maximum
MB	Millibar(s)
MBAM	Medium Beta and Advection Model
MCAS	Marine Corps Air Station
MCS	Mesoscale Convective System
MET	Meteorological
MIDDAS	Meteorological Imagery, Data Display, and Analysis System
MIN	Minimum
MINI-MET	Mini-Meteorological
MISTIC	Mission Sensor Tactical Imaging Computer
MM	Millimeter(s)
MOVG	Moving
MSLP	Minimum Sea-level Pressure
NARDAC	Naval Regional Data Automation Center
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NCTAMS	Naval Computers and Telecommunications Area Master Station
NEDN	Naval Environmental Data Network
NEDS	Naval Environmental Display Station
NESDIS	National Environmental Satellite, Data, and information Service
NESN	Naval Environmental Satellite Network
NEXRAD	Next Generation (Doppler Weather) Radar
NHC	National Hurricane Center
NM	Nautical Mile(s)
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NODDES	Naval Environmental Data Network Oceanographic Data Distribution and Expansion System
NODDS	Navy/NOAA Oceanographic Data Distribution System
NOGAPS or NGPS	Navy Operational Global Atmospheric Prediction System
NAVPACMETOCCEN	Naval Pacific Meteorology and Oceanography Center (Hawaii)
NAVPACMETOCCEN WEST	Naval Pacific Meteorology and Oceanography Center (Guam)
NPS	Naval Postgraduate School
NR	Number
NRL	Naval Research Laboratory

NRPS or NORAPS	Navy Operational Regional Atmospheric Prediction System
NSDS	Naval Satellite Display System
NSDS-G	Naval Satellite Display System - Geostationary
NTCC	Naval Telecommunications Center
NWP	Northwest Pacific
NWS	National Weather Service
OBS	Observations
OLS	Operational Linescan System
ONR	Office of Naval Research
OSS	Operations Support Squadron
OTCM	One-Way (Interactive) Tropical Cyclone Model
PACAF	Pacific Air Force
PACMEDS	Pacific Meteorological Data System
PACOM	Pacific Command
PCN	Position Code Number
PDN	Public Data Network
PIREP	Pilot Weather Report(s)
RADOB	Radar Observation
RECON	Reconnaissance
RECR	Recurve (Forecast Aid)
ROCI	Radius of outer-most closed isobar
RRDB	Reference Roster Data Base
RRT	Rapid Response Team
RSDB	Raw Satellite Data Base
RVP	Radial Velocity Product
SAT	Satellite
SEC	Second
SDHS	Satellite Data Handling System
SFC	Surface
SGDB	Satellite Global Data Base
SLP	Sea-Level Pressure
SPAWRSYSCOM	Space and Naval Warfare Systems Command
SSM/I	Special Sensor Microwave/Imager
SST	Sea Surface Temperature
STNRY	Stationary
ST	Subtropical
STR	Subtropical Ridge
STRT	Straight (Forecast Aid)
STY	Super Typhoon
TAPT	Typhoon Acceleration Prediction Technique
TC	Tropical Cyclone
TCFA	Tropical Cyclone Formation Alert
TCM-93	Tropical Cyclone Motion Mini-Field Experiment - 1993
TD	Tropical Depression
TDA	Typhoon Duty Assistant
TDO	Typhoon Duty Officer
TESS	Tactical Environmental Support System
TIROS-N	Television Infrared Observational Satellite-Next Generation
TOGA	Tropical Ocean Global Atmosphere
TOVS	TIROS Operational Vertical Sounder
TS	Tropical Storm
TUTT	Tropical Upper-Tropospheric Trough
TY	Typhoon
TYAN	Typhoon Analog (Forecast Aid)
TYMNET	Time-Sharing Network: Commercial wide area network connecting micro- and main-frame computers
ULCC	Upper-Level Circulation Center
US	United States
USAF	United States Air Force
USCINCPAC	Commander-in-Chief Pacific (AF - Air Force, FLT - Fleet)
USN	United States Navy
VIS	Visual
WESTPAC	Western (North) Pacific
WGTD	Weighted (Hybrid Aid)

WMO	World Meteorological Organization
WRN or WRNG	Warning(s)
WSD	Wind Speed and Direction
X-track	Cross-track
XTRP	Extrapolation
Z	Zulu time (Greenwich Mean Time/Universal Coordinated Time)

APPENDIX D

PAST ANNUAL TROPICAL CYCLONE REPORTS

Copies of the past Annual Tropical Cyclone Reports for DOD agencies or contractors can be obtained through:

Defense Technical Information Center
ATTN:FDAC
Cameron Station
Alexandria, VA 22304-6145

Phone: (703)-274-7633
Fax: (703)-274-9307

Copies for non-DOD agencies or users can be obtained from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

Phone: (703)-487-4650
Fax: (703)-321-8547

Refer to the following numbers when ordering:

Year	Acquisition Number	Year	Acquisition Number	Year	Acquisition Number
1959	AD 786147	1971	AD 768333	1983	AD A137836
1960	AD 786148	1972	AD 768334	1984	AD A153395
1961	AD 786149	1973	AD 777093	1985	AD A168284
1962	AD 786128	1974	AD 010271	1986	AD A184082
1963	AD 786208	1975	AD A023601	1987	AD A191883
1964	AD 786209	1976	AD A038484	1988	AD A207206
1965	AD 786210	1977	AD A055512	1989	AD A232469
1966	AD 785891	1978	AD A070904	1990	AD A239910
1967	AD 785344	1979	AD A082071	1991	AD A251952
1968	AD 785251	1980	AD A094668	1992	AD A274464
1969	AD 785178	1981	AD A112002		
1970	AD 785252	1982	AD A124860		

APPENDIX E
DISTRIBUTION LIST

1 COPY

ACCU-WEATHER, INC.
AEROMET, INC.
ANALYSIS & PROCESSING CENTER, INDONESIA
ARNOLD ASSOCIATES
ASIAN DISASTER PREPAREDNESS CENTER, BANGKOK, THAILAND
ATMOSPHERIC DIV LIBRARY, NEW ZEALAND
BARRETT CONSULTING GROUP
BRUNEI SHELL PETROLEUM CO
CATHOLIC UNIVERSITY OF AMERICA
CAF WEATHER CENTRAL, TAIWAN
CENTRAL MET OBSERVATORY, BEIJING
CENTRAL METEOROLOGICAL OFFICE, SEOUL
CHULALONGKORN UNIVERSITY, BANGKOK
CHUNG CHENG INSTITUTE, TAIWAN
CITY POLYTECHNIC OF HONG KONG
CIUDAD UNIVERSITARIA, MEXICO
CIVIL DEFENSE, CHUUK
CIVIL DEFENSE, MAJURO
CIVIL DEFENSE, PALAU
CIVIL DEFENSE, POHNPEI
CIVIL DEFENSE, SAIPAN
CIVIL DEFENSE, YAP
CINCPACFLT
CNN, ATLANTA, GA
CNO, WASHINGTON, D.C.
COMNAVMETOCCOM
COLORADO STATE UNIVERSITY LIBRARY
COMMONWEALTH NORTHERN MARIANA ISLANDS
COMNAVMAR
COMNAVSURFPAC, SAN DIEGO
COMPATRECFOR
COMPHIBGRU ONE
COMSCWESTPAC GU
COMSEVENTHFLT
COMSPAWARSYSCOM
COMSUBGRU SEVEN
COMTHIRDFLT
COMUSNAVCENT
CONGRESSIONAL INFORMATION SERVICE, MD
DCA GUAM
DET 2, 5WS CAMP HUMPHREYS, KOREA
DET 3, 5WS CAMP CASEY, KOREA
DISASTER CONTROL OFFICE, SAIPAN
ECONOMIC COUNCIL SAIPAN
EDMUNDS COLLEGE SOCIAL SCIENCE DEPT
ENVIRONMENTAL QUALITY PROTECTION BOARD, PALAU
FAIRECONRON ONE
FEDERAL EMERGENCY MANAGEMENT AGENCY, GUAM
FIJI METEOROLOGICAL SERVICE
GEOLOGICAL FLUID DYNAMICS LAB, PRINCETON, NJ
GEOLOGICAL SURVEY, GUAM
GEOPHYSICS LAB/LYS
GIFU METEOROLOGICAL OFFICE, JAPAN
GODDARD SPACE FLIGHT CENTER
GUAM COMMUNITY COLLEGE
GUAM POWER AUTHORITY
GUAM PUBLIC LIBRARY
HORIZON MARINE, INC
HQ AIR COMBAT COMMAND/OSW
HQ AWS
HQ AWS GROUP, ATC & WX WING JASDF, TOKYO
HQ US STRATCOM/J3615
HQ USAF/XOW
INDIA METEOROLOGICAL DEPT.
INDIAN INSTITUTE OF TROPICAL MET INSTITUO DE GEOFISICA, MEXICO
INTERNATIONAL CENTER FOR DISASTER MITIGATION, TOKYO
JAPAN AIR LINES
JCS ENV SERVICES DIV, PENTAGON
JET PROPULSION LAB, PASADENA
KOREAN METEOROLOGICAL ADMIN FORECAST BUREAU
LEND FOUNDATION
LISD CAMP SPRINGS CENTER, MD
LOS ANGELES PUBLIC LIBRARY
MARATHON OIL CO, TX
MAURITIUS METEOROLOGICAL SERVICE
MASS INST OF TECH
MCAS FUTENMA
MCAS IWAKUNI
MCAS KANEOHE BAY, HI
MERCANTILE AND GENERAL REINSURANCE, AUSTRALIA
METEOROLOGICAL DEPARTMENT, PAKISTAN
METEOROLOGICAL OFFICE, BRACKNELL
METEOROLOGICAL SERVICE, MADAGASCAR
METEOROLOGICAL SERVICE, MAURITIUS
METEOROLOGICAL SERVICE, REUNION
MIL ASST ENV SCI (R & AT / E &LS)
MOBIL OIL GUAM, INC
NASA
NATIONAL CLIMATIC DATA CENTER LIBRARY, ASHEVILLE,NC
NATIONAL METEOROLOGICAL CENTER
NATIONAL METEOROLOGICAL LIBRARY,

BRACKNELL, UK
NATIONAL TAIWAN UNIVERSITY
NATIONAL TECHNICAL INFORMATION SERVICE
NATIONAL WEATHER SERVICE, CHUUK
NATIONAL WEATHER SERVICE, MAJURO
NATIONAL WEATHER SERVICE, PALAU
NATIONAL WEATHER SERVICE, PAPUA NEW GUINEA
NATIONAL WEATHER SERVICE, POHNPEI
NATIONAL WEATHER SERVICE, SAIPAN
NATIONAL WEATHER SERVICE, YAP
NAVAL CIVIL ENG LAB PORT HUENENE, CA
NAVAL POSTGRADUATE SCHOOL LIBRARY
NAVAL RESEARCH LAB
NAVEURMETOCCEN, ROTA
NAVHISTCEN
NAVICECEN, SUITLAND
NAVLANTMETOCCEN, NORFOLK
NAVLANTMETOCDET, ASHEVILLE
NAVLANTMETOCFAC, JACKSONVILLE
NAVOCEANO
NAVPACMETOCDET, AGANA
NAVPACMETOCDET, ATSUGI
NAVPACMETOCDET, BAHRAIN
NAVPACMETOCDET, KADENA
NAVPACMETOCDET, SASEBO
NAVPACMETOCFAC, SAN DIEGO
NAVPACMETOCFAC, YOKOSUKA
NEW ZEALAND ATMOSPHERIC DIV LIBRARY
NEW ZEALAND INSURANCE
NOAA/ACQUISITION SECTION, ROCKVILLE, MD
NOAA/AOML, HRD, MIAMI, FL
NOAA, ATMOS TURB AND DIFFUSION DIV, OAK RIDGE, TN
NOAA/HYDROMETEOROLOGY BR, SILVER SPRINGS, MD
NOAA/NESDIS, HONOLULU, HI
NOAA/PMEL, SEATTLE, WA
NOAA ENVIRONMENTAL RESEARCH LAB
NOAA LIBRARY, SEATTLE, WA
NOBEL DENTON
NRL ATMOSPHERIC DIRECTORATE
OCEANROUTES, INC, JOLIMENT, WEST AUSTRALIA
OCEANROUTES, INC, SINGAPORE
OCEANROUTES, INC, SUNNYVALE, CA
OCEANWEATHER, INC
OFFICE OF FEDERAL COORDINATOR MET
OFFICE OF NAVAL RESEARCH
OFFICE OF THE NAVAL DEPUTY, NOAA
ONR
PACIFIC STARS & STRIPES
PACNAVFACENGCOM
PAGASA FORECAST SECTION
PAGASA LIBRARY
PENNSYLVANIA STATE UNIVERSITY
QUEENS COLLEGE, DEPT OF GEOLOGY
REUNION METEOROLOGICAL SERVICE
RUCH WEATHER SERVICE, INC
SAINT LOUIS UNIVERSITY
SAT APPL LAB, NOAA/NESDIS, WASHINGTON, DC
SHANGHAI TYPHOON INSTITUTE
SOUTHSIDE WEATHER SERVICE AUSTRALIA
SRI LANKA METEOROLOGICAL SOCIETY
SRI LIBRARY
TAO PROJECT OFFICE
TEXAS A & M UNIVERSITY
UNIV OF COLORADO, ATMOS SCIENCE
UNIVERSITY OF CHICAGO
UNIVERSITY OF GUAM, BIOLOGY DEPT
UNIVERSITY OF HAWAII LIBRARY
UNIVERSITY OF WASHINGTON
USAFETAC/DN
USCINCPAC
USCINCPAC REP GUAM
USNA (OCEANOGRAPHY DEPT/LIBRARY)
USS AMERICA (CV 66)
USS BELLEAU WOOD (LHA 3)
USS BLUE RIDGE (LCC 19)
USS CARL VINSON (CVN 70)
USS CONSTELLATION (CV 64)
USS EISENHOWER (CVN 69)
USS INDEPENDENCE (CV 62)
USS J. F. KENNEDY (CV 67)
USS KITTY HAWK (CV 63)
USS LINCOLN (CVN 72)
USS NEW ORLEANS (LPH 11)
USS NIMITZ (CVN 68)
USS PELELIU (LHA 5)
USS SARATOGA (CV 60)
USS TARAWA (LHA 1)
USS TRIPOLI (LPH 10)
USS T. ROOSEVELT (CVN 71)
USS WASP (LHD 1)
VANUATU METEOROLOGICAL SERVICE
WORLD DATA CENTER B1, MOSCOW
AFGWC/WFM
5WS WS/CC YONGSAN AIN KOREA
8 0SS/OSW KUNSAN AB, KOREA
15WS HICKAM AFB, HI
18 OSS/OSW KADENA AB, JAPAN
60 OSS/OSW TRAVIS AFB, CA
334 TTS/TTMV KEESLER AFB, MS
374 OSS/OSW YOKOTA AB, JAPAN
375 OG/WXF SCOTT AFB, IL
432 OSS/OSW MISAWA AB, JAPAN
603 ACCENS/WE OSAN AB, KOREA
633 OSS/OSW ANDERSEN AFB, GU

652 ABG/DOW MCCLELLAN AFB, CA
815 WS (AFRES), KEESLER AFB, MS

2 COPIES

AFGWC/WFMP
AWS TECH LIBRARY
BUREAU OF METEOROLOGY, BRISBANE
BUREAU OF METEOROLOGY, DARWIN
BUREAU OF METEOROLOGY LIBRARIAN, MELBOURNE
BUREAU OF METEOROLOGY, PERTH
BUREAU OF PLANNING, GUAM
CIVIL DEFENSE, GUAM
DEFENSE TECHNICAL INFORMATION CENTER
DEPARTMENT OF COMMERCE
ECMWF, BERKSHIRE, UK
ESCAP LIBRARY, BANGKOK
FLENUMETOCCEN MONTEREY
FLORIDA STATE UNIVERSITY
INSTITUTE OF PHYSICS, TAIWAN
MARINERS WEATHER LOG
MET RESEARCH INST LIBRARY, TOKYO
MICRONESIAN RESEARCH CENTER UOG, GUAM
NATIONAL CLIMATIC DATA CENTER
NATIONAL DATA BUOY CENTER
NATIONAL HURRICANE CENTER, MIAMI
NATIONAL WEATHER SERVICE, HONOLULU
NAVPACMETOCCEN
NAVPACMETOCDET DIEGO GARCIA
NAVPACMETOCDET MISAWA
NOAA GUAM
NORA 1570 DALLAS, TX
OKINAWA METEOROLOGY OBSERVATORY
SAT APPL LAB, NOAA/NESDIS, CAMP SPRINGS, MD
TYPHOON COMMITTEE SECRATARIAT, MANILA
UNIVERSITY OF PHILIPPINES
US ARMY, FORT SHAFTER
WORLD DATA CENTER A, NOAA
73 WEATHER GROUP, ROK AF

3 COPIES

BUREAU OF METEOROLOGY, DIRECTOR, MELBOURNE, AUSTRALIA
CENTRAL WEATHER BUREAU, TAIWAN
INDIA METEOROLOGICAL DEPT
INOSHAC, DDGM (WF)
JAPAN METEOROLOGICAL AGENCY
KOREAN METEOROLOGY ADMINISTRATION PLANNING BUREAU
NAVPGSCOL DEPT OF METEOROLOGY
NOAA CORAL GABLES LIBRARY
PACAF/DOW
UNIVERSITY OF HAWAII, METEOROLOGY DEPT
WEATHER CENTRAL, CAF

4 COPIES

COLORADO STATE UNIVERSITY
METEOROLOGY DEPT, BANGKOK

5 COPIES

R & D UNIT, NHC, MIAMI
ROYAL OBSERVATORY HONG KONG

6 COPIES

NRL WEST
NATIONAL WEATHER ASSOCIATION

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
AS IT APPEARS IN THE REPORT/
DISTRIBUTION UNLIMITED

4. PERFORMING ORGANIZATION REPORT NUMBER(S)

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
NAVPACMETOCCENWEST/JTWC

6b. OFFICE SYMBOL *(If applicable)*

7a. NAME OF MONITORING ORGANIZATION
NAVPACMETOCCEN/JTWC

6c. ADDRESS *(City, State, and ZIP Code)*
COMNAVMAR, PSC 489, BOX 12
FPO AP 96536-0051

7b. ADDRESS *(City, State, and ZIP Code)*
COMNAVMAR, PSC 489, BOX 12
FPO AP 96536-0051

8a. NAME OF FUNDING / SPONSORING ORGANIZATION
NAVPACMETOCCENWEST/JTWC

8b. OFFICE SYMBOL *(If applicable)*

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS *(City, State, and ZIP Code)*
COMNAVMAR, PSC 489, BOX 12
FPO AP 96536-0051

10. SOURCE OF FUNDING NUMBERS
PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO | WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*
1993 ANNUAL TROPICAL CYCLONE REPORT

12. PERSONAL AUTHOR(S)

13a. TYPE OF REPORT
ANNUAL

13b. TIME COVERED
FROM JAN 93 TO DEC 93

14. DATE OF REPORT *(Year, Month, Day)*
1993

15. PAGE COUNT
243 plus i thru vi

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
04	02	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
TROPICAL CYCLONES
TROPICAL STORMS
TROPICAL DEPRESSIONS
TYPHOONS/SUPER TYPHOONS
TROPICAL CYCLONE RESEARCH
METEOROLOGICAL SATELLITES

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

ANNUAL PUBLICATION SUMMARIZING TROPICAL CYCLONE ACTIVITY IN THE WESTERN NORTH PACIFIC, BAY OF BENGAL, ARABIAN SEA, WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEANS. A BEST TRACK IS PROVIDED FOR EACH SIGNIFICANT TROPICAL CYCLONE. A BRIEF NARRATAIVE IS GIVEN FOR ALL TROPICAL CYCLONES IN THE WESTERN NORTH PACIFIC AND NORTH INDIAN OCEANS. ALL FIX DATA USED TO CONSTRUCT THE BEST TRACKS ARE PROVIDED UPON REQUEST ON DISKETTES. FORECAST VERIFICATION DATA AND STATISTICS FOR THE JOINT TYPHOON WARNING CENTER (JTWC) ARE SUBMITTED.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL
FRANK H. WELLS

22b. TELEPHONE *(Include Area Code)*
(671)-344-5240

22c. OFFICE SYMBOL
JTWC

BLOCK 18 (CONTINUED)

RADAR
AUTOMATIC METEOROLOGICAL OBSERVING STATIONS
SYNOPTIC DATA
TROPICAL CYCLONE INTENSITY
TROPICAL CYCLONE BEST TRACK DATA
TROPICAL CYCLONE FORECASTING
TROPICAL CYCLONE RECONNAISSANCE
TROPICAL CYCLONE STEERING MODELS
OBJECTIVE FORECASTING TECHNIQUES
TROPICAL CYCLONE FIX DATA
MICROWAVE IMAGERY
DRIFTING BUOYS